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ORIGINAL ARTICLES.

New Scottish and Irish Fossil Crinoids.

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(PLATES XIII–XV.)

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I. Introduction.

THE purpose of this paper is to place on record some interesting occurrences of crinoids in the Scottish and Irish Carboniferous Limestones. Some of the descriptions of new species are preliminary to a fuller study of the subject.

I am much indebted to Dr. John Pringle for the loan of three specimens belonging to the Scottish Geological Survey. One is an almost complete Inadunate crinoid from Cove Harbour, Cocksburnpath, the other two are Flexible crinoids collected by the late John Smith at Auchenskeith, Ayrshire. In addition, I am able to give a photograph of another Flexible species collected by the late James Thomson at the same locality. I also take this opportunity of thanking Dr. George A. Cumming, of the Geological Department, St. Andrew's University, for the loan of seven specimens, and the privilege of examining others, collected by himself from the Encrinite bed at St. Andrew's.

The Irish specimens were collected at Hook Head, Co. Wexford, during a visit to that interesting region last year, when I was accompanied by my friends Mr. Jas. L. Begg, of Mount Vernon, Glasgow, and Mr. John Skinner, of Kirkcaldy. I must here express my indebtedness to Dr. L. B. Smyth, of Trinity College, Dublin, not only for his kindness in connection with our visit but also for presenting me with some crinoids collected by himself at Hook Head during his work on that locality (1930). The purpose of our visit was to collect specimens for comparison with the Scottish forms and to see how far the Irish fauna differed from or agreed with that of Scotland or England. The Irish specimens we collected are numerous and very interesting and some are detailed herein. The larger question, however, i.e. the critical comparison of the faunas, cannot be dealt with at present. So far, the visit has strengthened an opinion which has been growing in recent years, namely, that the crinoid fauna of the Scottish Carboniferous Limestones is quite distinct in that *Actinocrinus*, *Amphoracrinus*, *Gilbertsocrinus*, and perhaps *Cyathocrinus*, which are typical English and Irish Carboniferous Limestone genera, are non-existent in the Scottish rocks and that the fauna of the latter contains genera and species peculiar to it. In some of its elements this fauna also, while probably more prolific in species, is more akin to that of the Yoredale Series in England, the Russian Bergkalk near Moscow, and the Chester or Kaskasia of the U.S.A.

One of the best collections of Hook Head crinoids in this country is that contained in the Liverpool Public Museum. It was made by the Austins about a hundred years ago and some of the specimens are described and figured by these authors in their Monograph published in 1843. On visiting the Liverpool Museum in August last year I noted certain of the specimens and later Dr. Douglas Allan, the Director, was kind enough to send them to me for examination. I must here express my grateful thanks to Dr. Allan not only for the privilege of handling the specimens but also for the loan of Fort Major Austin's MS. copy of the catalogue of the collection, the perusal of which has been illuminating as to the specimens described or intended to be described by the Austins.

II. Scottish Species.

Dicyclica inadunata, Bather.
Dendrocrinoidea, Bather.
Poteriocrinidae, Roemer (emend. Wachs. & Spring.).
Poteriocrininae, Springer.

1. *Cromyocrinus geminatus* Trautschold.

Pl. XIII, Figs. 1, 2, 3, Text-figs. 1, 2.

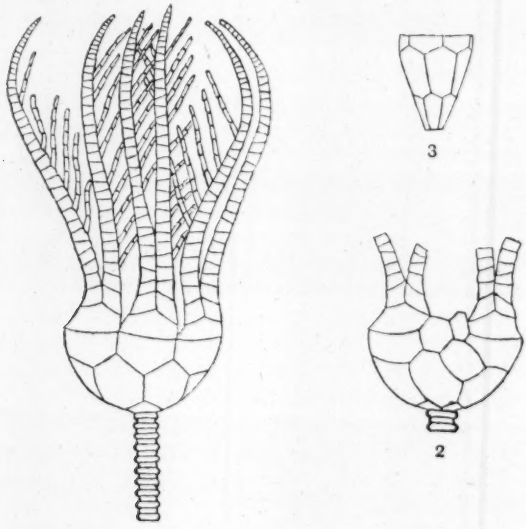
1867. *Bull. Soc. Imper. des Nat. de Moscou*, xl, pt. ii, 25, pl. 4, fig. 6.
1879. *Nouv. Mem. Soc. Imper. des Nat. de Moscou*, xiv, pt. i, 22, pl. iii, figs. 5 and 6.

Specimens which appear to me to belong to Trautschold's species, *Cromyocrinus geminatus*, have recently been found by Dr. G. A. Cumming, of the Geological Department, St. Andrew's University, and by myself, in the Encrinite bed on the shore in front of St. Andrew's. The specimens, which are fairly numerous, are now in the Geological Department of the University and in my own collection. They consist mostly of crowns but some have a good part of the column in position. The cups are generally crushed, although the arms are as a rule beautifully preserved. The cup plates are thin and seem rather thinner than typical Russian specimens of the species, but this may be partly or wholly due to conditions of deposit. Judging from two examples of *C. geminatus* and other Moscow species in my collection, the Russian bed seems to consist mainly of a chalky white, rather soft limestone, with the crinoids occurring in the body of the rock and little crushed, whereas the St. Andrew's specimens occur on the weathered surfaces of thin and generally hard, irony limestone bands packed full of the dismembered ossicles of crinoids. Occasionally a specimen is found on the shales overlying or underlying such bands.

In essential characters of the species, there seems no difference in our specimens. The cups are shown from all sides and on a few the radial facets can be seen. The general bowl shape, disposition of the anal plates, infra-basal circlet, etc., all agree with Trautschold's species. The arm structure is also similar, i.e. each ray has one primibrach and the arms only fork once. This type of structure is of course also characteristic of *Eupachycrinus calyx* (McCoy), but in this species the arms are heavy and rounded, composed of short, quadrangular brachials with almost parallel sutures, not unlike those of *Woodocrinus macrodactylus* de Kon. In *C. geminatus* the brachials are higher, relatively narrower plates, tending to be cuneiform, and the arms taper more gradually, giving a finer and more elegant appearance to the specimens.

Text-figs. 1 and 2 are generalized drawings from the specimens and photographs are shown on Pl. XIII, Figs. 1, 2, and 3. No traces of a ventral sac can be seen, although many of the arms are spread out with the pinnules still adherent. The maximum length of a crown is about 2 inches or 50 mm., and a good average size is about

1½ in. or 38 mm. The column, while well shown in some specimens, is not found complete. On one of my slabs, however, it measures over 9 inches in length. This specimen and others show that where it joins the cup it is nodular in character, composed of narrower and wider columnals, but at a short distance from the cup it tends to become smooth, of more or less equal thickness, and continues so for the remaining length. It is round throughout. Very few traces of cirri were observed.



FIGS. 1 and 2.—*Cromyocrinus geminatus* Trautschold. Anterior and posterior views.

FIG. 3.—*Hydriocrinus* sp. from Encrinite bed, St. Andrew's. All figs. nat. size.

The Encrinite bed of East Fife has long held interest for geologists, but the occurrence of this well-defined species seems to be the first authentic record from the bed, or for that matter from any other horizon in Britain. One notes, however, that the Rev. T. Brown, in presenting his well-known pioneer paper to the Royal Society of Edinburgh (1860, p. 398), says, "Among those [specimens] here produced is a small head of a *Poteriocrinus* taken from the bed L [i.e. the Encrinite bed] the base of the Mountain Limestone, a little to the south of the Rock and Spindle." This specimen may have been a *Cromyocrinus geminatus*, since it seems to be the prevailing species in the Encrinite bed of the St. Andrew's area.

2. *Hydriocrinus* sp.

Pl. XIII, Fig. 11, Text-fig. 3.

Apart from *Cromyocrinus geminatus*, the only other record from the Encrinite bed is a cup found by Dr. Cumming in the outcrop

in front of St. Andrew's (Pl. XIII, Fig. 11, Text-fig. 3). (I have since found a similar cup minus the radials and a bundle of arms which probably belong to the same species.) Although this cup does not show the anal side and seems to have somewhat higher basals and relatively shorter radials, it has a high infra-basal circlet and altogether a general habitus greatly resembling Trautschold's genus *Hydriocrinus*, also from the Russian Carboniferous (1867, 1879). The St. Andrew's cup is not to be confused with *Ulocrinus globularis* de Kon. or its varieties as they occur in Scotland and England (Bather, 1917; Wright, 1927), and it is therefore here referred to *Hydriocrinus* sp.

No other Russian forms have so far been recognized in the Encrinite bed, but it is interesting to recall the occurrence of another Russian species, *Synerocrinus incurvus* Trautschold, in the Ardross Limestone, a higher horizon in the Calciferous Sandstones of East Fife (Wright, 1914; Springer, 1920).

Finally, it has to be noted that the Geological Survey list *Actinocrinus triacontadactylus* Miller and *Poteriocrinus* sp. from the Encrinite bed in front of St. Andrew's (1902). Through the kindness of Dr. J. Pringle, I have seen the specimens which were collected by the late James Bennie from this bed and from which these two records are given. The name *Actinocrinus triacontadactylus* is placed opposite the number B 3917*g* in the Scottish Geological Survey records. The specimens are in a small box and consist mainly of small crinoid stems and ossicles and five small crushed cups which probably belong to *Cromyocrinus geminatus*. They certainly have nothing to do with *Actinocrinus*. The record *Poteriocrinus* sp. is opposite No. B 3968*g*, which is a tablet on which are mounted four stem ossicles, possibly belonging to *Cromyocrinus*, but that is all one can say about them. All the crinoid remains collected by Mr. Bennie from the Encrinite bed consist of material which has evidently been obtained from washing the shale interspersed with and overlying or underlying the crinoid limestone bands, and among the mounted specimens I was interested to find that there are at least thirty-two infra-basal circlets of the cups of *Cromyocrinus geminatus*. These are numbered as follows: twenty-eight circlets on tablets B 3932*g* to B 3937*g*, one on B 3990*g*, one on B 3999*g*, and two on B 4013*g*. Of special interest also is a box No. B 3920*g* in which can be easily identified three infra-basal circlets of the same type of cup found by Dr. Cumming and referred above to *Hydriocrinus* sp.

3. *Eupachycrinus ardrossensis* sp. nov.

Pl. XIII, Figs. 9, 10; Pl. XIV, Figs. 2, 8, 9, Text-figs. 4, 5.

1924. Cf. *Cromyocrinus geminatus* Trautschold. Wright, GEOL. MAG., LXI, 277.

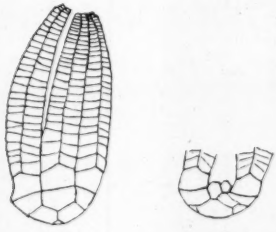
Diagnosis.—A small species; cup forming a low cone with smooth, sloping sides; IBB just visible from the side; anal area usually constricted; IBr one; arms ten, heavy and rounded as in *E. calyx*.

Affinities.—Near to *E. calyx* McCoy, but smaller and differs in shape of cup.

Holotype.—J. Wright Collection No. 2216.

Paratypes.—J. Wright Collection Nos. 2217, 2218, 2219.

Locality.—Ardross Limestone, Fife, Calciferous Sandstone Series. Also at Peter's Crook, Liddesdale.



4 5

FIGS. 4 and 5.—*Eupachycrinus ardrossensis* nov. Anterior and posterior views. Nat. size. Ardross, Elie. J. W. Colln.

Since the discovery of *Cromyocrinus geminatus* in the Encrinite bed at St. Andrew's, referred to in the foregoing pages, I have again examined several cups and crowns which I found many years ago in the Ardross Limestone between Elie and St. Monance. In 1924 I compared these specimens with others found at Peter's Crook in Liddesdale, and referred them all with considerable doubt to cf. *Cromyocrinus geminatus*. In view of the evidence afforded by the St. Andrew's specimens, I think this determination is wrong, and that all the Fife and Liddesdale specimens are better placed under *Eupachycrinus* and in a distinct species from that of *E. calyx*. Our cups are considerably smaller than the average of *E. calyx* as found in Fife and elsewhere, and like that species are stoutly built and composed of rather thick plates. In *E. calyx*, basals and radials are somewhat tumid plates; in the species under discussion the cup is in the form of a low cone with smooth, sloping sides and with infra-basals just visible when viewed from the side. The anal plates are usually constricted or bent inwards at the top, with the result that the upper corners of right and left posterior radials project beyond the line of the anals. This type of structure is not common in *E. calyx* and may point to some difference in the ventral sac. In some respects our form is intermediate between *E. calyx*, which has a saucer-shaped cup, and IBB not usually discernible in a side view, and *C. geminatus*, with bowl-shaped cup, in which the IBB are distinctly visible from the side.

The crowns from Ardross show the arms very well, and although all the specimens are smaller than the average *E. calyx*, the arms are the same in plan and structure. The cup, however, being of a different shape, a distinct habitus is given to the specimens and so

makes them easily distinguishable. On account of this difference I propose the name *E. ardrossensis* for their reception. The number of specimens is as follows :—

Ardross .	. 5 cups and 3 crowns.
Peter's Crook	. 5 cups and 1 crown.
Largest cup, in diameter	. 12 mm.
Smallest cup, in diameter	. 8 mm.
Height of average crown	. 32 mm.

The cups in all specimens show the normal type of anal area, except one from Ardross in which the usual plan is reversed, i.e. RA to the left of post. B. (Wright, 1926, 156).

4. *Eupachycrinus stellaris* sp. nov.

Pl. XIII, Figs. 12 and 13.

1912. *Eupachycrinus* No. 2 sp., Wright, *Trans. Edin. Geol. Soc.*, x, 49.
1918. *Eupachycrinus* No. 2 sp., Wright, *Trans. Geol. Soc., Glasgow*, xvi, 364.
1925. *Eupachycrinus* No. 2 sp., Wright, *Trans. Edin. Geol. Soc.*, xi, 288.

Diagnosis.—Cup saucer-shaped, of moderate size ; average diameter 8 mm. ; central area much depressed ; IBB small, sunk in concavity and invisible from the side ; BB conspicuous giving a star-like appearance to the cup ; plates coarsely pustular.

Holotype.—J. Wright Collection, No. 2222*a*, Pl. XIII, Fig. 13.

Locality.—No. 3 Bed, Invertiel. Also occurs at Chapel, Roscobie, and in the Seafield Tower Limestone, near Kirkcaldy.

In various papers I have recorded from No. 3 Bed, Invertiel, and other localities in Fife, cups to which I gave the name of *Eupachycrinus* No. 2 sp. to distinguish them from the commoner cups of *E. calyx*. Two of these specimens are shown on Pl. XIII, Figs. 12 and 13. They are flat, saucer-shaped cups not unlike some small specimens of *E. calyx*, but the central area is more depressed or concave and the plates have a coarse, pustular ornamentation. The infra-basals are very small, sunk well down in the concavity of the cup and almost entirely covered by the column. No traces of arm structure have yet been found, but in the meantime, to distinguish the cups from others which occur at Invertiel, Roscobie, and other places, and which clearly belong to species not yet described, I give them the name of *E. stellaris*. I have examined a number of cups belonging to this species but all have the normal type of anal area.

5. *Decadocrinus fifensis* sp. nov.

Pl. XIV, Figs. 5 and 7, Text-figs. 6–18.

Diagnosis.—A small species ; height of crown, 14 mm. or more ; cup deeply bowl-shaped ; IBB taking little part in calyx wall, sunk in concavity and invisible from the side ; BB tumid ; RR flaring ; anal area variable ; IBr one, $2\frac{1}{2}$ times higher than RR ; $IIBr_1$ about two-thirds height of IBr ; arms ten ; other IIBr becoming shorter

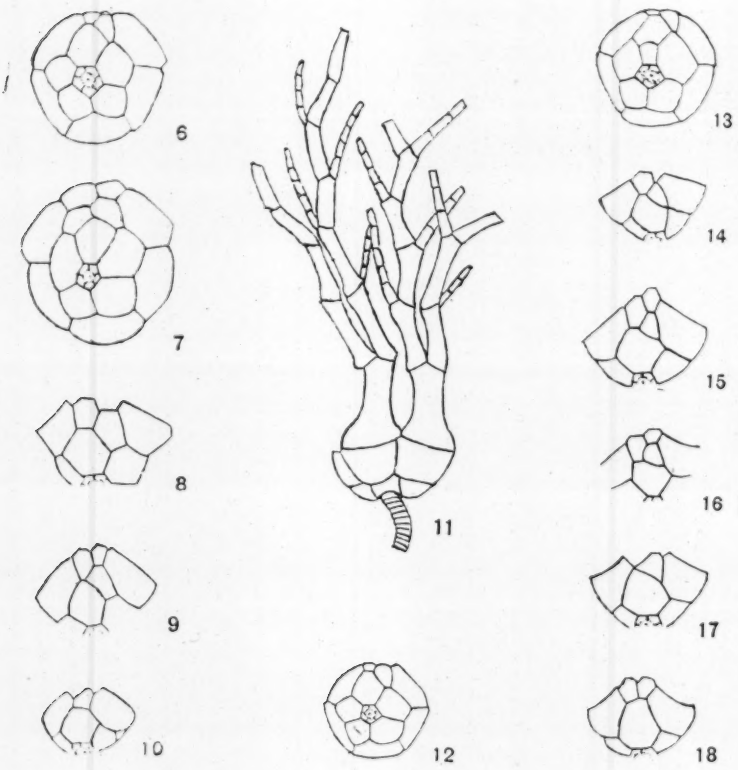
distally ; IIBr 6 to 8 or more, with long pinnules given off from each alternate upper corner ; surface smooth or very finely frosted.

Holotype.—J. Wright Collection, No. 128.

Locality.—Roscobie, Fife.

Paratypes.—J. Wright Collection, Nos. 2223-2246.

Locality.—No. 1 Bed, Invertiel.



FIGS. 6 to 18.—*Decadocrinus fifensis* sp. nov. Fig. 11 from Roscobie, all the others from Invertiel. J. W. Colln. × 4.

When looking for specimens of *Allagecrinus* in washed shale from No. 1 Bed, Invertiel (Wright, 1932), I found forty-three small cups, beautifully preserved, which I could not with any confidence refer to any Scottish species known to me. The smallest measures less than 2·5 mm. in diameter and the largest does not exceed 5 mm. The cups are of the *Eupachycrinus calyx* type with similar radial facets, but are rather deeply bowl-shaped, not the flat saucer form of *E. calyx*, which is one of the commonest species in this bed at Invertiel. The IBB form only a small proportion of the cup. The basals, however, are decidedly tumid and the radials somewhat

flaring so that the cups have a habitus peculiar to themslves. Among the Invertiel crinoids, perhaps the nearest with which they can be compared are the much larger cups of *Hydreionocrinus* which occur in Nos. 2 and 3 Beds (Wright, 1926). These, however, have a rather coarse ornamentation, of which there are no traces in our specimens and they have other differences also. The question, of course, arises as to whether our small cups are really not the young of a species belonging to *Eupachycrinus* or some other genus. I think it can at least be said that they are not young forms of *E. calyx*, since they exist side by side with undoubtedly similar sized specimens of this species, and both forms are easily distinguished one from the other. As for *Hydreionocrinus*, this genus occurs only in Nos. 2 and 3 Beds at Invertiel. I have never seen in any of the beds at this locality any cups which could be looked upon as intermediate between the largest of the small specimens and the smallest of the large *Hydreionocrinus*, so that I think we may regard our specimens as fairly normal in size and as belonging to a species distinct from any of the known forms at Invertiel. A clue to their real nature is given in two specimens from Roscobie in which there is some evidence of the arms. In the Invertiel specimens no traces of arm structure are preserved except in one cup in which a single primibrach is attached. This, which is a long, narrow plate, agrees with the primibrachs shown in the two specimens from Roscobie, one of which, although flattened, shows a good part of two rays, and there is no reason to doubt that the species is the same since the cups are similar ; also detached brachials of the same nature are frequently found in the shale of No. 1 Bed at Invertiel. The Roscobie specimen is shown on Pl. XIV, Fig. 5, Text-fig. 11. The length of this crown is about 14 mm., but the distal parts of the arms are missing, so that it must have been longer. The arm structure, with the long, narrow brachials from which on alternate upper corners rather long pinnules are given off, seems to be essentially of the *Decadocrinus* type. I accordingly place the specimens under this genus. As to the species, I have examined most of the figures of American forms, some of which are comparatively small, but none quite agree. The nearest in shape of cup and arm structure are probably *D. penicilliformis* Worthen and *D. fountainensis* Worthen (1882). The former has a crown about 23 mm. in length with a rounder cup and smoother outlines and relatively shorter brachials. The latter, so far as preserved, is about 16 mm. in length and is probably the nearest, but the cup here is shallower than ours. Of course, in comparing these and other species, I have always borne in mind that our figured specimen may be a young individual, and in fact, judging from the diameter of its cup, which is 4 mm., the Fife species attained a larger size, since the diameter of the largest cup from Invertiel is 5 mm. In actual length, therefore, our species may have come very near to *D. fountainensis*. Even so, it seems that our species differs from this and other American species chiefly in the shape of the cup. Another point on which it may

differ is a tendency to variability in the anal area. I have examined the forty-three cups from Invertiel and find that in thirty the anal area is of the normal type as shown in Text-figs. 6, 8, and 12, with the usual slight variations in relative size and disposition of RA, X, and rt. The remaining thirteen show modifications like those of Text-figs. 7, 9, 10, 13–18.

Decadocrinus has not hitherto been recognized in the Scottish Carboniferous rocks, and considering the small size of our specimens this is perhaps not surprising. Other species of the genus no doubt occur in Fife and in other localities. There is probably at least another small one at Invertiel. The specimens consist of detached, long, narrow brachials, the same as those noted in *D. fifensis*, but with a very coarse surface ornamentation, associated with exceedingly flat saucer-shaped cups similarly decorated. The specimens, however, are not yet worked out.

Another specimen in my collection which may belong to this species is shown on Pl. XIV, Fig. 4. It is from the Lower Carboniferous Limestones at Cass-ny-hawin, Isle of Man. The cup here, however, is rather crushed and difficult to see as to details, but the arms so far as preserved are identical.

6. *Scytalocrinus covensis* sp. nov.

Pl. XIV, Fig. 1, Text-fig. 21.

Diagnosis.—Cup conical; arms five, brachials cuneate, rounded, narrow, more or less quadrangular distally, tending to biserial in lower parts. Height of crown, 65 mm.; height of cup, 7·6 mm.; width at top, 7 mm.

Holotype.—Scottish Geological Survey Collection, No. B 3700*c*.

Locality.—Cove Harbour, Cocksburnpath. Calciferous Sandstone Series.

7. *Scytalocrinus arbiglandensis* sp. nov.

Pl. XIV, Fig. 6, Text-fig. 19.

Diagnosis.—Cup conical, relatively wider at top than in previous species; arms five, brachials moderately cuneate, stout, not so rounded as in previous species; length of arms unknown; height of cup, 7 mm.; width at top, 12 mm.

Holotype.—J. Wright Collection, No. 75.

Locality.—Arbigland, Solway Firth. Calciferous Sandstone Series.

8. *Scytalocrinus pentonensis* sp. nov.

Pl. XIV, Fig. 3, Text-fig. 20.

Diagnosis.—Cup conical; arms five, brachials heavy, markedly cuneate, ridged and almost triangular in section, slight tendency to biserial in lower parts; height of crown, 73 mm.; height of cup, 7 mm.; width at top, 7 mm.

Holotype.—J. Wright Collection, No. 2247.
Locality. — Penton Linns, Liddesdale. Lower Carboniferous Limestones.

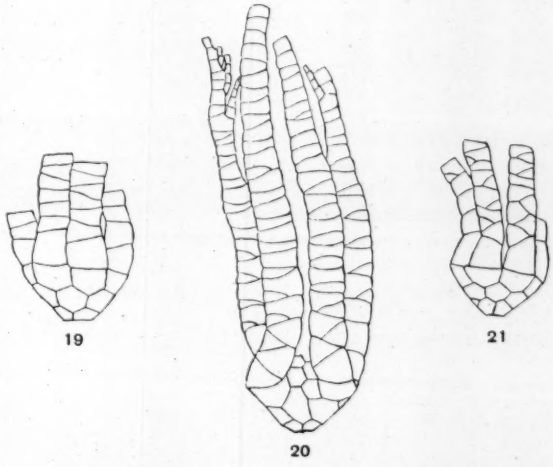


Fig. 19.—*Scytalocrinus arbiglandensis* sp. nov.
Fig. 20.—*S. pentonensis* sp. nov.
Fig. 21.—*S. covensis* sp. nov. All nat. size.

The three specimens figured and illustrated probably belong to a genus like *Scytalocrinus*, although their exact position is difficult to establish. All three have a conical or bell-shaped cup with five arms only, i.e. one arm to each ray. The arms are composed for the most part of cuneiform brachials tending in one specimen to be quadrangular in the upper regions. In the genus *Scytalocrinus* the arms are given as ten, although in certain species a single arm only is present in the anterior ray. As far as I have been able to find out, however, no other genus seems suitable for the reception of our specimens, so unless we are to create a new genus it seems best to place them here meantime. Except for the single-armed character, the specimens have a general habitus not unlike such species as *S. gracilis* (Troost) (1909) or *S. validus* Wachs. and Spring. (1926). In the three specimens before us we appear to have three distinct species. *S. covensis*, Pl. XIV, Fig. 1, Text-fig. 21, is the most elegant form with long arms which in the lower parts have a tendency to a biserial arrangement. This is not specially apparent in *S. arbiglandensis*, Pl. XIV, Fig. 6, Text-fig. 19, which has somewhat clumsier arms altogether. The acme of clumsiness, however, is found in *S. pentonensis*, Pl. XIV, Fig. 3, Text-fig. 20, in which the arms are extremely thick, giving this crinoid a top-heavy appearance, if one may use such an expression, the cup being small in proportion.

The anal area in the cups is only seen in *S. pentonensis*, but is presumably the same in the other two species. All three cups are a little flattened and are drawn so in the figures, but making due allowance for this, that of *S. arbiglandensis* is relatively wider at the top.

9. *Abrotocrinus angustatus* sp. nov.

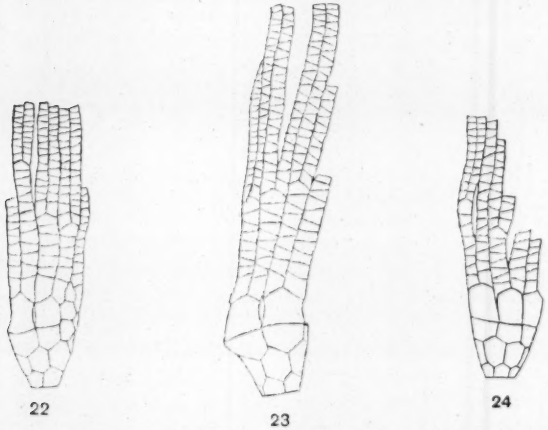
Pl. XIII, Figs. 4–6, Text-figs. 22–4.

Diagnosis.—Cup turbinate, anal area normal; column markedly pentagonal, tapering rapidly below cup; IBr one; IIBr not less than 6, usually more; ventral sac long, narrow, cylindrical, composed of large stellate plates; plates of cup and arms ornamented with fine granules and wrinkles.

Holotype.—J. Wright Collection, No. 2220.

Paratypes.—J. Wright Collection, Nos. 2221, 2211.

Locality.—Ardross Limestone, Elie. Calciferous Sandstone Series.



FIGS. 22–4.—*Abrotocrinus angustatus* sp. nov. Figs. 22 and 24, left and right posterior views of No. 2220. Fig. 23, left posterior view of No. 2221. J. Wright Colln. Ardross Limestone, Elie. Nat. size.

The specimens referred to the above species consist of three crowns of which two are figured on the plate and text-figures. In one of the specimens a good part of the ventral sac is exposed, Pl. XIII, Figs. 5 and 6. It is long, narrow, and cylindrical, composed of somewhat coarse stellated plates not unlike the plates of the sac of *Parisocrinus subramosus* Miller and Gurley, figured by Dr. Springer (1911). The stellate plates in our species, however, are relatively much larger, only three full plates being seen in a side view, i.e. comprising the width of the sac. I have not been able to detect the anal opening, and the best preserved specimen is broken at the distal end. The arms are also of slender build and when closed round the narrow sac give the specimens a peculiarly constricted appearance.

The plates of cup and arms have a beautiful granular and wrinkled ornamentation. The full arm branching is not preserved in any of the specimens. What is seen is plotted in the text-figures. The column is markedly pentagonal throughout the length preserved, which is 3 inches in the specimen shown on Pl. XIII, Fig. 4. It tapers very rapidly from the first or second columnal, giving the species a characteristic aspect.

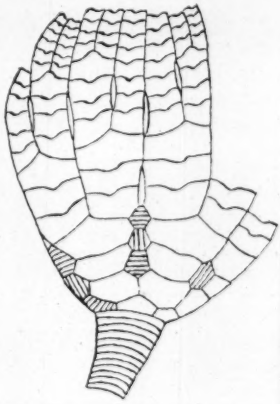
FLEXIBILIA Zittel.

ICHTHYOCRINIDAE Angelin (emend. Wachs. & Spring.).

10. *Synerocrinus? smithi* sp. nov.

Pl. XIII, Figs. 8, 14, Text-figs. 25, 26.

Diagnosis.—A small species ; crown elongate, rounded below from column facet, expanding upward ; IBB small, entirely within ring of BB ; post. B rising nearly to height of RR, truncate, followed by other plates in a single series ; IBr one to three ; arms dichotomous, more or less divergent.



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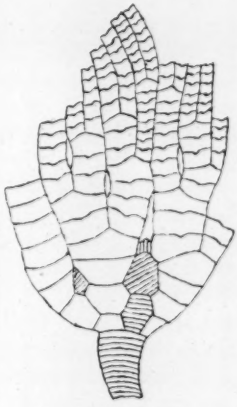

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FIGS. 25 and 26.—*Synerocrinus ? smithi* nov. × 1½. Anal and interbrachial plates shaded. Colln. of Scottish Geological Survey.

Holotype.—Scottish Geological Survey Collection, No. JS 12094.

Locality.—Auchenskeith, Ayrshire. Lower Carboniferous Limestones.

Among the fossils collected by the late John Smith from Auchenskeith, Ayrshire, and now in the collection of the Scottish Geological Survey, are the two Flexible crinoids referred to in the introduction. They are registered under Nos. JS. 12094 and JS. 12095. Unfortunately, the specimens are not well preserved, both consisting of flattened crowns showing imperfectly one side only.

I have tried to make the drawings as accurate as possible, but in No. JS. 12095, Text-fig. 25, it is extraordinarily difficult to detect the suture lines between the plates. The other specimen, No. JS. 12094, Text-fig. 26, is much flattened, but the plates can be easily seen. Both specimens apparently belong to the same species, although the arm branching in the higher series does not quite agree. The number of IIBr and IIIBr is, however, sometimes variable in other species, as for example in *Eutaxocrinus fletcheri* Worthen ("*Crinoidea Flexibilia*," pl. L, figs. 15 and 16). The specimens, too, are incomplete and do not show the full extent of the arms even in the rays which are preserved. Text-fig. 25 is also a larger and probably more mature individual. Since they agree in all other characters, such as number of primibrachs which is two, the comparatively small number of interbrachials, the arms which are dichotomous, rounded, and somewhat divergent, and probably in the character of the anal area, it seems best to regard them as one species. The anal area is better shown in the smaller specimen, Text-fig. 26. Here, the posterior basal is followed by a large plate, slightly displaced in the specimen, which appears to have had a close connection with the adjoining brachials. It is followed by a small plate now partly imbedded in the matrix. On the left of the other specimen, Text-fig. 25, one notes a series of plates which evidently connect up with the post. basal and must therefore be the anal series. On their right they are closely fitted in with the brachials and there is probably a similar connection on their left, although the specimen is crushed at this point.

In comparing these specimens, one finds they do not agree with any species of Flexibilia hitherto described from the Scottish Carboniferous, and there are only two species with which detailed comparisons can be made, namely, *Amphicrinus scoticus* Springer and *Synerocrinus incurvus* Trautschold. With *A. scoticus* our specimens only agree in the structure of the anal area, in so far as the plates seem connected with the brachials, but in *A. scoticus* the anal plates are usually in a double series. In other details, such as number of interbrachials and arm structure, they are quite dissimilar. With *Synerocrinus incurvus* there is more agreement. The anal area is evidently the same. I have a typical specimen of this species from the Seafield Tower Limestone, near Kirkcaldy, which has a single series of anal plates fitted into the anal area in the same manner as in the Auchenskeith specimens. In the latter the interbrachials are less numerous than in *S. incurvus*. Perhaps the greatest difference is in the arms, which in *S. incurvus* are heterotomous with heavy ramules. At the same time I have compared the specimens with American forms having two primibrachs with which they seem to be closely related, the nearest apparently being *Eutaxocrinus fletcheri* (Worthen) from the Lower Carboniferous of the U.S.A. With this species there is considerable agreement in the structure of the arms and in the small number

of interbrachials, and one would have little hesitation in referring the specimens to *Eutaxocrinus* were it not for the structure of the anal area which in this genus is of the Taxocrinoid type. As far as we can see, the anal area in the Auchenskeith specimens is of the Ichthyocrinid type.

In discussing these matters one has to remember that the specimens only number two and are very imperfect. On the whole and considering the importance of the anal structure in Dr. Springer's classification of the Flexibilia, I am at present inclined to place them better under *Synerocrinus* until we know more about them, and until preserved material is forthcoming to clear up the matter. Although the type of arm structure is different and the specimens conceivably belong to a new genus, this seems the better course. The species is obviously new and is named in memory of the discoverer. Apart from the arms, the only difference from *S. incurvus* is the smaller number of interbrachials.

11. *Eutaxocrinus* ? sp.

Pl. XIII, Fig. 7, Text-fig. 27.

1925. Cf. *Taxocrinus communis* Hall. Wright, *Trans. Edinb. Geol. Soc.*, xi, 289.

The specimen referred to this species belonged to the Thomson Collection, which was partly destroyed in the disastrous fire at the Kilmarnock Museum in 1912. Mr. Lawrence, Curator of the Museum, informs me that the specimen cannot now be found, so we must assume that it was not recovered from the salvage.

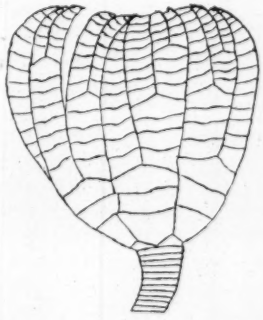

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Fig. 27.—*Eutaxocrinus* ? sp. drawn from cast of a specimen formerly in the Kilmarnock Museum. × 1½. Auchenskeith, Ayrshire.

The photograph reproduced is a copy of a print which was given to me over twenty years ago by the late Robert Dunlop, who also gave me a cast of the specimen. In the above cited paper I referred

to this cast and stated the species might belong to *Taxocrinus*, and in the list which I gave I recorded the species under cf. *Taxocrinus communis* Hall. I have again examined the photograph and cast very carefully. It is, of course, one thing examining a photograph and cast and quite another the actual specimen itself, but it is now perfectly clear to me in the cast that the number of primibrachs is two, so that the species does not come under *Taxocrinus*, but is more akin to *Eutaxocrinus*. The number of IIBr and IIIBr is a matter of doubt because these plates are obscure in the cast. I have, however, tried to plot them out in the drawing, Text-fig. 27. As far as can be seen there are no interbrachials at all and the anal area is not shown. Any reference of this cast must therefore be a matter of guesswork. In the rounded nature of the arms it agrees with the John Smith specimens already dealt with although the branching is obviously different. Meantime I give the photograph and drawing in the hope that other specimens will be forthcoming to throw light on the species, and also as an interesting record of a crinoid collected by the late James Thomson, one of the band of great collectors in the West of Scotland in former days.

III. Irish Species.

Dicyclica inadunata Bather.
Poteriocrininae Springer.

1. *Pachylocrinus latifrons* (Austin).

Pl. XV, Figs. 9, 10, 16.

1843–9. *Poteriocrinus latifrons* Austin, *Mon. Rec. & Foss. Crinoidea*, 82, pl. x, fig. 4.

Specimens probably belonging to this species were found by us in the Upper *Michelinia favosa* Beds at Hook Head. Dr. L. B. Smyth also records the species from the same horizon (1930). The Austins' figured specimen is said to come from the Mendips, but Dr. Douglas Allan informs me it cannot now be found. Two specimens which agree fairly well with both description and figure are shown on Pl. XV, Figs. 9 and 16. Fig. 9 shows an example with the ventral sac in position. The sac here is considerably weathered on one side and is composed of rather heavy hexagonal plates, the whole structure being somewhat cylindrical but tending to swell out at the top. Fig. 16 is a younger specimen of the species with the arms closely folded. Fig. 10 on the same plate is a photograph of a specimen, No. 62 of the Austin Collection, labelled *Poteriocrinus abbreviatus* Austin, from Hook Head, which probably also belongs to *P. latifrons*. It may be compared with Fig. 7 of Pl. XV, which is a photograph of *P. brevidactylus* Austin (syn. *P. abbreviatus* Austin). This species is dealt with below. The two specimens are quite different.

2. *Pachylocrinus brevidactylus* (Austin).

Pl. XV, Fig. 7.

1843. *Cladocrinites brevidactylus* Austin, *Ann. Mag. Nat. Hist.*, xi, 198.
1843–9. *Poteriocrinus abbreviatus* Austin, *Mon. Rec. & Foss. Crinoidea*, p. 89, pl. xi, fig. 4*a*.
1886. *Taxocrinus brevidactylus* (Austin), Wachs. & Spring., *Revision of the Palaeocrinoidea*, p. 332, author's reprint.

In the *Revision of the Palaeocrinoidea* Wachsmuth and Springer list under *Taxocrinus* the Austins' species *Poteriocrinus* (*Cladocrinites*) *brevidactylus* (syn. *P. abbreviatus* Austin) from Hook Head, having apparently taken the drawing of the species on pl. xi, fig. 4*a*, in the Austins' Monograph (1843–9) to be that of a Flexible crinoid. Later, however, Dr. Springer seems to have had doubts about this interpretation since in *The Crinoidea Flexibilia* (1920, 383) the name is not placed in the list of authentic species of *Taxocrinus*, but under a list of those which are either synonyms, insufficiently known, or do not belong to the Flexibilia. He further remarks that the species probably belongs to the Taxocrinidae and might be *Eutaxocrinus*. As a matter of fact I am now able to state that the specimen which is No. 61 of the Austin Collection is not a Flexible crinoid at all, but a typical Inadunate form of which a photograph is shown on Pl. XV, Fig. 7, accompanying this paper. Among several other specimens labelled *Poteriocrinus abbreviatus* in the Austin Collection, No. 61 is easily identified as the one drawn on pl. xi, fig. 4*a*, of the Monograph. This is confirmed by the descriptions of *Cladocrinites brevidactylus* in *Ann. Mag. Nat. Hist.* (1843, 198), and of *Poteriocrinus abbreviatus* which appeared later in the Monograph. Both descriptions obviously refer to this specimen, and the Austins state in the latter publication that *C. brevidactylus* is a synonym of *P. abbreviatus*.

Specimen No. 61, upon which these descriptions are based, is somewhat imperfect, only a portion of the arms being preserved. About 1 inch of the column is in position surmounted by a typical obconical dicyclic cup, slightly squeezed, with three of the radials well shown. The anal area is not seen. The radial facets are straight with the brachials upon them occupying the full width. The radial on the left and that in the middle bear two primibrachs after which the arms fork. On the right of specimen the arm plates are slightly distorted, but can be easily counted, and I was surprised to find that the radial here bears eight primibrachs before the bifurcation takes place. At least ten secundibrachs are preserved, i.e. on the left ramus of this ray. The ray in the middle is displaced, but in the right ramus of ray on left of specimen nine secundibrachs are seen, the top one being axillary. It is clear that the arms were much longer than are shown in the specimen, or in the figure given by the Austins, as indeed they thought. Possibly the rays forked several times as in *P. longidactylus* figured alongside on the same plate.

According to Dr. Springer's definition of genera of the sub-family Poteriocrininae (1911, 1926), the genus to which this species belongs is probably *Pachylocrinus*, although in the character of the ray on the right it has something in common with *Culmicrinus*. This, however, may be an abnormality since we can see nothing of the rays imbedded in the matrix. It seems best, therefore, meantime to record the species in our lists as *Pachylocrinus brevidactylus* (Austin).

Here it may be mentioned that another specimen from Hook Head in the Austin Collection, No. 64, is labelled *Poteriocrinus brevidactylus* Austin, our Text-fig. 31, Pl. XV, Fig. 5. This name also appears against No. 64 in the MS. catalogue. Now as it happens, this is a true Flexible crinoid with general habitus quite distinct from No. 61 just dealt with. It is therefore puzzling to understand how the Austins could confuse this specimen with the others labelled *P. abbreviatus* since, as already stated, they regarded the latter as synonymous with their *P. brevidactylus*. Unless some mistake has been made in the numbering of the specimens since the Austins' time, we can only assume that they looked upon No. 64 as the same species as No. 61, but owing to the fine preservation of both specimens I find this difficult to believe. However that may be, No. 64 belongs to the Flexibilia and is now considered as an example of *Onychocrinus polydactylus* (McCoy). Its structure and affinities are discussed on a later page along with other specimens of the group we found at Hook Head.

Graphiocrininae Bather.

3. *Graphiocrinus smythi* sp. nov.

Pl. XV, Fig. 8, Text-fig. 28.

Diagnosis.—Cup saucer shape, IBB just visible in side view ; arms ten ; IBr one, about three times higher than RR ; $IIBr_1$ about same height as IBr ; other IIBr becoming shorter distally ; ventral sac very narrow, cylindrical, extending beyond arms, composed of a double series of quadrangular plates ; column pentagonal near cup.

Holotype.—J. Wright Collection, No. 2252.

Dimensions of Holotype.—Height of crown, 32 mm. ; height of cup, 2 mm. ; width of cup, 7·5 mm. ; height of RR, 1·5 mm. ; height of IBr, 3·3 mm.

Locality.—Supra-dolomite Beds, Hook Head, Co. Wexford.

Several examples referred to the above species were found at Hook Head, but the one figured is the best preserved and is taken as the type. The cup, with the single plate in the anal inter-radius, is typical of the genus. The specific name is given in honour of Dr. L. B. Smyth, who has so admirably elucidated the rocks of this region (1930). The nearest species with which I have been able to compare the Irish forms is *G. wachsmuthi* (Worthen), which has

arms very similar in structure. The cup, however, is conical in this species. In our type the arms are well shown, also a good part of the ventral sac, which is long and narrow, composed in the main of alternating thick and thin plates arranged in a double series opposite to one another. The lower part where it joins the anal X is not preserved and at the top some plates are missing. It is of uniform thickness throughout the length preserved, Text-fig. 28. I have another three specimens of the species all showing the anterior side and Mr. Begg has another, but none of them show the ventral sac. The arms only fork once. In each ray a long narrow single primibrach, which is axillary, rests on the radial. The primibrachs

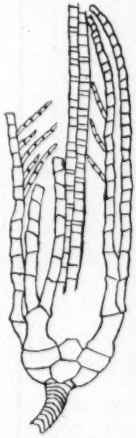

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FIG. 28.—*Graphiocrinus smythi* nov. × 1½. Figure of the type from Hook Head. J. W. Colln.

are about three times the height of the radials. The first secundibrachs are somewhat less in height and succeeding brachials become gradually shorter. The cup in this species is saucer-shaped, although in the figure and photograph it is shown somewhat flattened. The IBB are just visible from the side. About 9 mm. of the column is still in position. It is distinctly pentagonal at the top, becoming gradually less so, and at about 5 mm. from the cup tends to be more or less round. It is nodular in character throughout, but in the proximal region the columnals are thinner. The total height of the crown in the type specimen is 32 mm. *Graphiocrinus encrinoides* de Kon. and Le Hon is recorded by Dr. Smyth from the Upper *Michelinia favosa* Beds at Hook Head. The specimen is typical of the species, the arms being composed of short quadrangular brachials not elongated as in the present form and the specimen is about the same in height.

FLEXIBILIA Zittel.
TAXOCRINIDAE Wachsmuth, emend. Springer.

4. *Onychocrinus polydactylus* (McCoy).

Pl. XV, Fig. 5, Text-fig. 31.

1844. *Taxocrinus polydactylus* McCoy, *Synopsis Carb. Foss. Ireland*, 178, pl. xxvi, fig. 7.
1920. ? *Onychocrinus polydactylus* (McCoy), Springer, *The Crinoidea Flexibilia, with other references*, 439, pl. lxiv, figs. 11–14.

Among the crinoids from Hook Head are seven specimens which clearly belong to the Flexibilia. Two of these are in Mr. J. L. Begg's collection and four in my own. I am indebted to Dr. L. B. Smyth for the specimen shown on Pl. XV, Fig. 3, which was collected by himself at Hook Head. Included in this total is the specimen No. 64 of the Austin collection, already alluded to when dealing with *Pachylocrinus brevidactylus*. In this section we deal specially with the last-named specimen, but before discussing it certain facts must first be noted.

Flexible crinoids are evidently very rare in the Irish Carboniferous, the only recorded species being *Taxocrinus polydactylus* McCoy (1844), the type specimen of which is said to come from Bundoran. Dr. Springer (1920) accepts this species as a characteristic member of the Flexibilia and places it under *Onychocrinus* with some reservations. McCoy also records Phillips' *Taxocrinus macrodactylus* from two localities near Dungarvan. This, however, is primarily a Devonian species and I have no information about the specimens. One may note in passing that Dr. W. E. Schmidt (1930) records this species from the Lower Carboniferous of Germany.

All seven specimens consist of somewhat flattened crowns, all with the exception of one showing side views. Their appearance may be gathered from the photographs on Pl. XV, Figs. 1–6, and Text-figs. 29–33. Text-fig. 29, Pl. XV, Fig. 1, is a specimen belonging to Mr. Begg, which gives a view of the base. The specimens as a whole are comparatively small and exhibit some irregularities in number of primibrachs. In the discrimination of genera and species, Dr. Springer lays special stress on the number of primibrachs and character of the arms. From these aspects he is not too confident in placing McCoy's *Taxocrinus polydactylus* under *Onychocrinus* since, although it agrees in general habitus, it differs in the great extension of the primary brachials, which he says are unique among the Flexibilia, and in the position of the ramules which, contrary to the usual order, branch to the inside of the dichotom. He further remarks: " we do not know enough of its structure to determine with certainty its generic relations, but it presumably has the weak anal side consistent with its greatly extended and divergent rays, and therefore will belong somewhere near the company in which I have placed it " (1920, 439). In *O. polydactylus*, which has a height of 70 mm. or more, the number of primibrachs is given as six or more, although one notes in the figure of the species (1920,

pl. lxiv, fig. 12) that the middle ray only shows five. The specimen of *Poteriocrinus egertoni* Phillips (1836), figured on the same plate, which has a height of 35 mm., is said to come from Enniskillen, and is considered with good reason by Dr. Springer to be a young example of *O. polydactylus*. It also has five and six primibrachs in the exposed rays. We can see, therefore, that this species is variable as to number of primibrachs in the order of five to six. This fact is significant in the present case because two of our specimens exhibit a similar discrepancy in the number of these plates, in the lower order however of three to four, and excluding the Austins' No. 64, none of the specimens shows a greater number of primibrachs than four. In this respect they differ considerably from *O. polydactylus*.

The Austins' specimen No. 64, Pl. XV, Fig. 5, Text-fig. 31, is the only one among the Hook Head material which compares well with *O. polydactylus*, and agrees with it in having five primibrachs in the three exposed rays. In other characters, such as number of IIBr and structure of the arms, it also compares well. Some traces of interbrachials can be seen. In the inter-ray on the left, a single hexagonal plate is visible. In the right inter-ray a similar plate is no doubt there, but owing to weathering and distortion at this point it is difficult to see although I have drawn it in the figure. No interbrachials are shown in the figure of the type specimen of *O. polydactylus* but, as in the Austins' specimen, a single interbrachial is also shown in the left inter-ray of the figure of *O. egertoni*. Ramules are not well shown in the Austins' specimen and are now only represented by some scattered plates more or less hidden in the matrix near the tips of the arms. The apparent absence of these elements is possibly one reason why the Austins confused this specimen with their *P. brevidactylus*. At all events, considering the other resemblances and making due allowance for the small size of the specimen, it is reasonable to assume that these structures are the same as in *O. polydactylus*. We, of course, know comparatively little about *O. polydactylus*, which is based on two fragmentary specimens, but we can see that it attained a large size at the Bundoran locality and that the prevailing numbers of primibrachs are five and six. The Austins' specimen is only 21 mm. in height, otherwise its characters, so far as we know them, are indistinguishable, and we are forced to the conclusion that it is probably a young or earlier representative of the species. The Hook Head limestones are on a somewhat lower level than the Bundoran series from which *O. polydactylus* is recorded, and the Austins' specimen may well denote the first appearance of the species in the Irish area. For the present, therefore, I regard the Austins' No. 64 as a young example of *O. polydactylus*.

5. *Onychocrinus hibernicus* sp. nov.

Pl. XV, Figs. 1–4, 6, Text-figs. 29, 30, 32, 33.

Diagnosis.—A small aberrant species; crown elongate to ovoid; IBr variable 3 to 4; IIBr 3 to 5; RA when present, in primitive

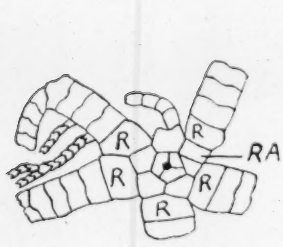
position under right post. R ; iBr well developed in older specimens ; ramules fine in structure, springing from both sides of dichotom and low in rays ; bifiurcating after second up to sixth ossicle ; sutures arcuate ; surface of plates finely granular or smooth.

Affinities.—Near to *Onychocrinus polydactylus* (McCoy), but a smaller species with ratio of IBr 3 to 4 instead of 5 to 6 or more.

Holotype.—J. Wright Collection, No. 2251.

Paratypes.—J. L. Begg Collection (two specimens) ; J. Wright Collection, Nos. 2248, 2249, 2250.

Locality.—Supra-dolomite Beds, Hook Head, Co. Wexford.



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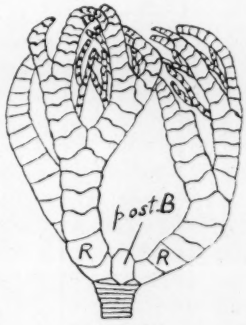

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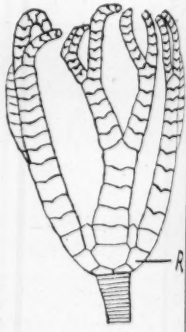

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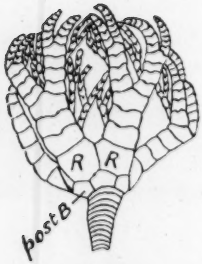

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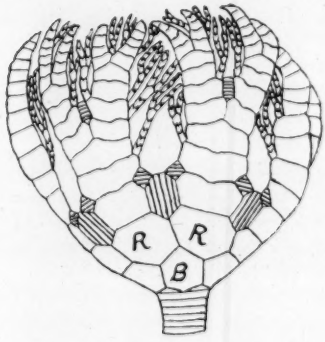

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FIGS. 29, 30, 32, and 33.—*Onychocrinus hibernicus* sp. nov. ; Fig. 31, *O. polydactylus* (McCoy) ; Fig. 31 is drawn from specimen No. 64, Austin Colln., Liverpool Public Museum ; Fig. 29, J. L. Begg Colln. ; Figs. 30, 32, and 33, J. Wright Colln. All from Hook Head. × 1½.

Turning now to the other six specimens, it has already been indicated that they show some distinctive features from *O. polydactylus*, although it is clear enough that they belong to the same genus. As with *O. polydactylus*, certain of their characters differ

from the true *Onychocrinus* type. I am not, however, so much concerned with this aspect of the subject at present, and as a matter of convenience, following Dr. Springer, I place them in this genus meantime. Before discussing the relationship of the specimens let us consider their details.

	IBr.	*IIBr.*	*Height of crown.*
Pl. XV, Fig. 1, Text-fig. 29 .	4	4	15 mm.
„ „ 2 . . .	4	4	15 „
„ „ 3, Text-fig. 32 .	3·4	4	13·8 „
„ „ 4 „ 30 .	4·3	5	20 „
„ „ 6 „ 33 .	3	4	23 „
Specimen not figured . .	3	3·4	16 „

It will be seen that the six specimens, while having a general resemblance to one another, differ somewhat as to numbers of primibrachs. Beginning with the smallest, Text-fig. 32, in the two middle rays exposed, the number of primibrachs is three and secundibrachs four. This agrees with the largest specimen, Text-fig. 33, and the general appearance of the two specimens is remarkably alike, so much so in fact that first impressions inclined me to think that both belonged to a species different from the other specimens. On developing the small specimen further, however, it was found that the ray on the right has four primibrachs, and we cannot tell the number of these plates in the rays which are hidden in the matrix. The same remark, of course, applies to the largest specimen which only fully shows the details of two rays. One of the other specimens, belonging to Mr. Begg and not figured since it is considerably squeezed, shows that the number of primibrachs in two rays is three and secundibrachs three and four. Another specimen of about the same size, Pl. XV, Fig. 2, has four primibrachs and four secundibrachs in one ray, the others being distorted. Another one, Text-fig. 30, has in the ray exposed on the left four primibrachs and secundibrachs four and five. In the ray on the right, the primibrachs number three and secundibrachs five and five. Altogether, there are three specimens showing three primibrachs, one of which has a ray with four, and three specimens with four primibrachs, one of which has a ray with three.

As regards other structures, the only one which shows evidence of interbrachials is the largest specimen, Text-fig. 33, Pl. XV, Fig. 6. This specimen is much weathered, but the three interbrachials in the three inter-rays are clearly seen. It is also interesting to find a small, narrow interbrachial dividing the $IIBr_2$ in the two middle rays. This specimen is probably the most mature example of the series and measures 23 mm. in height. Taking this as the maximum height, it would seem that these specimens represent a smaller species altogether which did not attain anything like the height of *O. polydactylus*.

Text-fig. 29 and Pl. XV, Fig. 1, represent a small specimen, which

is interesting not only because it shows in two rays exposed on the left that it has four primibrachs, but also from the fact that the base is well seen with a plate, which I take to be the radianal in the primitive position under the right posterior radial, also a part of the anal tube plates. These last are characteristically of the Taxocrinid type, and in this repect the anal side is therefore similar to *Onychocrinus*. The position of the radianal is, however, unusual for the genus, since when present this plate is stated to be always in the upper oblique position. Here then seems to be another point of difference from the true *Onychocrinus* type, the character being more akin to *Protaxocrinus*. No other specimen shows the radianal in position.

In all the specimens traces of ramules can be detected. Some are better preserved than others, and especially beautiful are those shown on the specimens figured on Pl. XV, Figs. 3, 4, and 6, Text-figs. 30, 32, and 33. As to whether the ramules are precisely the same as in *O. polydactylus* is not quite clear. Allowing for the difference in size of the specimens, they appear to be relatively much finer, being very thin compared with the rays and at first sight look more like pinnules. In most cases they are clustered round the tips of the arms. As far as can be made out, they spring off from each side of the dichotom as well as low down in the rays. Their exact point of attachment is difficult to detect and in the drawings the positions are only approximate. That they are true ramules is clearly seen in the specimens. They spring off from the ray as a single series of plates, numbering in some cases as many as seven, after which they bifurcate.

From the evidence given above it will be seen that we have here a somewhat variable assemblage which as a whole do not strictly conform to any fixed rule so far as number of primibrachs is concerned. How then are we to deal with them ? The matter might, of course, be looked at in various ways. To begin with, can they possibly be regarded as younger examples of *O. polydactylus* ? We have seen that in this species the number of primibrachs is also variable, although in the higher number of these plates, and that our specimens are closely related admits of no question. Their small size and agreement in general habitus, etc., do not, however, I think, warrant us in considering them as young forms in the ordinary sense of the term at any rate. This view is supported by the fact that, as a group, they are uniformly small and the largest specimen is a mature individual. They have also relatively finer ramules, which, so far as one can see, are different in position and branching. All the specimens only show the three and four primibrach plan as compared with the five and six of *O. polydactylus*, with no connecting link between the two plans. As we have seen, the only specimen among the Hook Head material which, on the evidence, can reasonably be regarded as a young example of *O. polydactylus*, is the Austins' No. 64, which we have already referred to

this species. In size, it comes in under our largest specimen, Text-fig. 33, and consistently shows the five primibrach plan in its three exposed rays. The occurrence of this specimen, on a lower horizon than that of the type, seems to indicate that the five primibrach character was thus definitely fixed for the species and that we may expect to find it in even smaller specimens.

It now remains to consider whether (1) the six specimens could be regarded as forming two distinct species according to the chief number of primibrachs, i.e. three and four IBr, or whether (2) they should all be grouped under one and the same species. As regards (1), considering the intergradations between the three and four primibrach plans in our specimens, coupled with the evidence of *O. polydactylus* itself, this idea, besides appearing somewhat illogical, does not seem feasible. It is true that had the largest specimen, Text-fig. 33, been found alone, and we had only one of the others, e.g. Text-fig. 30, with which to compare it, the two forms would probably have been considered quite distinct. In spite of the apparent difference, however, the other specimens clearly show that there is a close connection between them. It might be thought that it is stretching a point to include with the others such a specimen as Text-fig. 33, with its well-developed interbrachials and comparatively broad primibrachs, but making due allowance for this being a very mature individual, having only three primibrachs, there is nothing else specially to distinguish it. Thus if we look at the younger specimen, Text-fig. 32, and confine attention to the two middle rays, which like the mature specimen have only three primibrachs and four secundibrachs, the two forms are similar except in size and in the absence of interbrachials in the younger specimen, which might be expected. On the other hand, our small specimen has four primibrachs in the right ray which connects it to the three specimens having four primibrachs, while one of these also has only three primibrachs in one ray. Thus the two series are intimately linked up and in practice it is impossible to separate them. So we come to (2), which seems to me to be the preferable course, that is to group all six specimens under one and the same species, a species which was apparently in an extremely plastic condition as to number of primibrachs and in which these plates were liable to run from three to four. In *O. polydactylus*, the tendency was evidently in the higher series, from five to six and possible more. I accordingly propose the name *hibernicus* for the reception of our specimens. Whether our new form, along with *O. polydactylus*, ought to be retained under *Onychocrinus* or removed to another and perhaps new genus, cannot now be decided, and is a matter for further study and the acquisition of more material.

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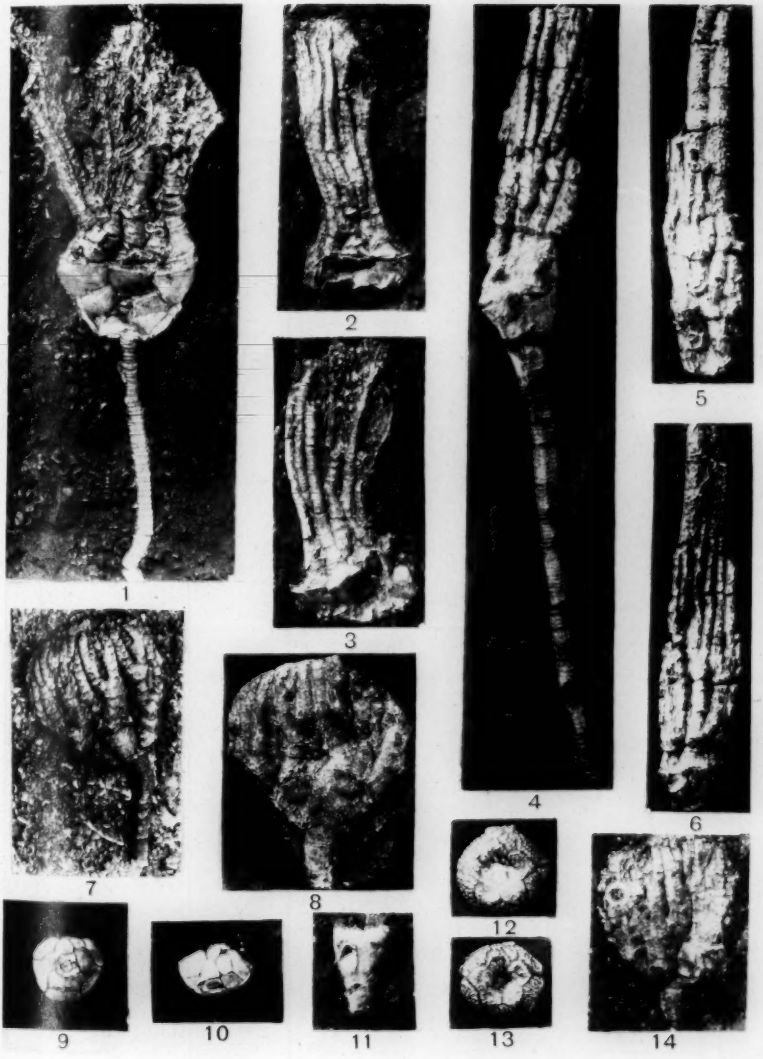
V. Explanation of Plates XIII–XV.

Plate XIII.

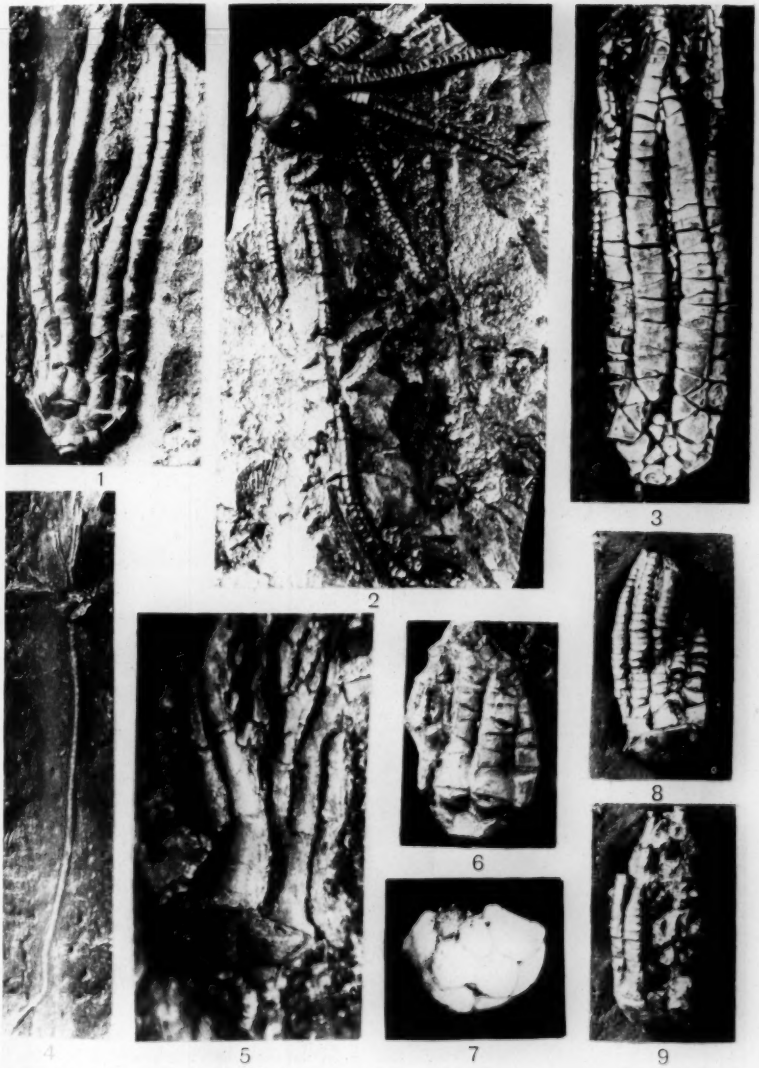
Figs. 1 and 3, *Cromyocrinus geminatus*, Trautschold, J. Wright Colln., Nos. 2256 and 2257. Fig. 2, the same species, Colln. of Geological Department, University, St. Andrews. All three specimens are from the Encrinite-bed, in front of St. Andrews. Fig. 4, *Abrotocrinus angustatus* sp. nov., J. Wright Colln., No. 2220. Note the pentagonal column tapering rapidly from the cup downwards. Ardross, Elie. Figs. 5 and 6, the same species, shown from two sides. The arms are broken about midway with the ventral sac extending much beyond



J. Wright, photo.

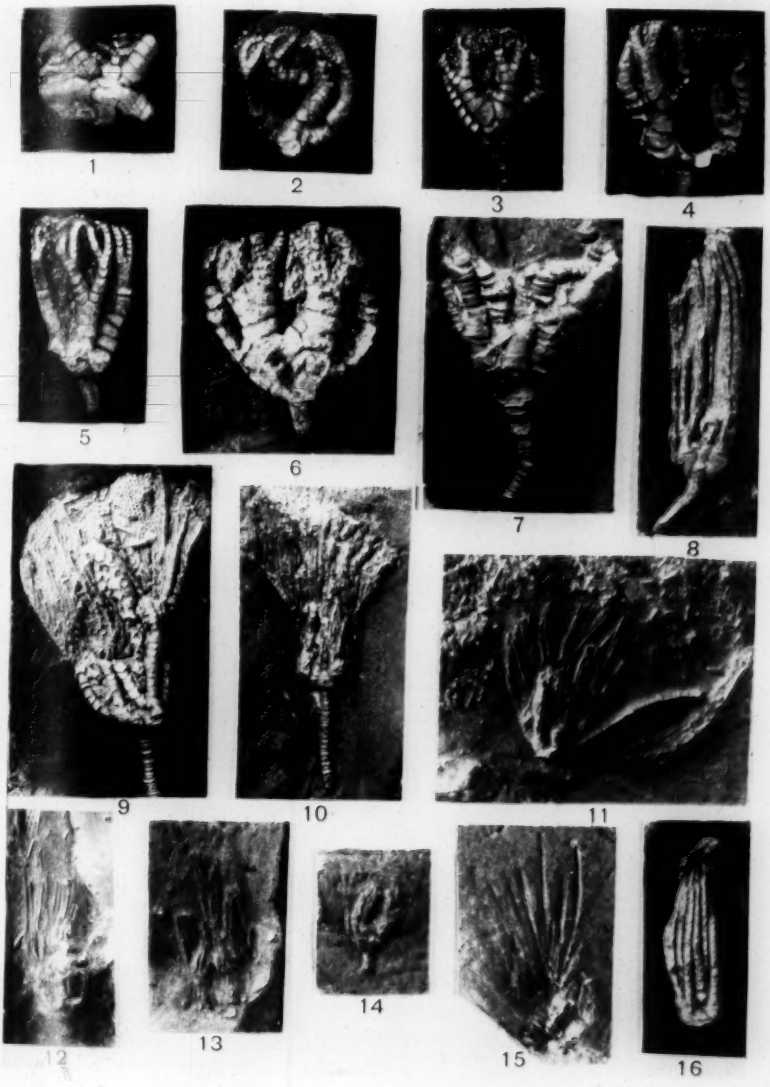
CRINOIDS FROM SCOTLAND.

[*To face p.* 266.



J. Wright, photo.

CRINOIDS FROM SCOTLAND AND ISLE OF MAN.



J. Wright, photo.

CRINOIDS AND BLASTOIDS FROM HOOK HEAD, IRELAND.

the broken portions. J. Wright Colln., No. 2221, Ardross, Elie. Fig. 7, *Eutaxocrinus* ? sp., photograph of a specimen formerly in the Thomson Colln., Kilmarnock Museum. Figs. 8 and 14, *Synerocrinus* ? *smithi* sp. nov., Scottish Geological Survey Colln., Nos. JS 12095 and JS 12094, from Auchenskieth, Ayrshire. Figs. 9 and 10, cups of *Eupachycrinus ardrossensis* sp. nov. from Ardross, J. Wright Colln., Nos. 2219 *a* and *b*. Fig. 11, *Hydriocrinus* sp., Geological Department, University, St. Andrews, Encrinite-bed, St. Andrews. Figs. 12 and 13, *Eupachycrinus stellaris* sp. nov., J. Wright Colln., Nos. 2222 *a* and *b*, No. 3 Bed, Invertiel. All figs. ⅔ nat. size except Figs. 9 and 10, which are × 1½.

PLATE XIV.

FIG. 1, *Scytalocrinus covensis* sp. nov., Scottish Geological Survey Colln., Royal Scottish Museum, Edinburgh, No. B 3700*e*, from Cove Harbour, Cockburnspath. Fig. 2, *Eupachycrinus ardrossensis* sp. nov., J. Wright Colln., No. 2218, from Ardross, Elie. Fig. 3, *Scytalocrinus pentonensis* sp. nov., J. Wright Colln., No. 2247, from Penton Linns, Liddesdale. Fig. 4, probably *Decadocrinus*, from Cass-ny-hawin, Isle of Man, J. Wright Colln., No. 603. Fig. 5, crown of *Decadocrinus fifensis* sp. nov., J. Wright Colln., from Roscobie, No. 128. Fig. 6, *Scytalocrinus arbiglandensis* sp. nov., J. Wright Colln., No. 75, from Arbigland, Solway Firth. Fig. 7, cup of *Decadocrinus fifensis* sp. nov., from Invertiel, J. Wright Colln., No. 2223*a*. Figs. 8 and 9, two views of a crown of *Eupachycrinus ardrossensis* sp. nov. from Ardross, J. Wright Colln., No. 2216. All figs. ⅔ nat. size, except Figs. 5 and 7, which are × 4.

PLATE XV.

FIGS. 1, 2, 3, 4, and 6, *Onychocrinus hibernicus* sp. nov. Fig. 1, J. L. Begg Colln. Figs. 2, 3, 4, and 6, J. Wright Colln., Nos. 2249, 2250, 2248, and 2251. Fig. 6 is the holotype. Fig. 5, *Onychocrinus polydactylus* (McCoy), No. 64, Austin Colln., Liverpool Public Museum. Fig. 7, *Pachylocrinus brevidactylus* (Austin), No. 61, Austin Colln. in the Liverpool Museum. This is the specimen figured by the Austins in their monograph as *Poteriocrinus abbreviatus* and thought by Wachsmuth and Springer to be a flexible crinoid. Fig. 8, *Graphiocrinus smythi* sp. nov., the type, J. Wright Colln., No. 2252. Figs. 9 and 16, *Pachylocrinus latifrons* (Austin), J. Wright Colln., Nos. 2258 and 2259. Fig. 10, probably the same species, No. 62, Austin Colln., Liverpool Museum. All figs. ⅔ nat. size.

Note on the Occurrence of Blastoids with Brachioles at Hook Head, Co. Wexford, Ireland.

By JAMES WRIGHT, F.G.S., F.R.S.E.

(PLATE XV, FIGS. 11–15.)

AMONG interesting finds at Hook Head are several specimens of a species of Blastoid with the brachioles in position. A few also have part of the column attached. The species has not yet been worked out, but it probably belongs to the genus *Orophocrinus*. The calices are mostly crushed and for that reason may be difficult to identify, but so far as a somewhat cursory examination has shown they belong to a species similar to *O. pentangularis* Miller. Blastoids

in this condition do not seem to have been recorded from European rocks before. In the *Catalogue of the Blastoidea in the Geological Department of the British Museum*, published in 1886, Etheridge and Carpenter state on p. 63 that no traces of brachioles have been discovered in any European Blastoid. I do not know of any record since. They are rarely found in this state of preservation even in America, so it seems worth while placing the specimens on record now. Dr. L. B. Smyth records *Orophocrinus pentangularis* Miller from the Upper *Michelinia antiqua* Beds at Hook Head, also a Blastoid from the Upper *Michelinia favosa* Beds, but he informs me he has never seen any of these organisms in the above state of preservation before. Our specimens occurred on a thin shaly layer on top of a limestone in the Supra-dolomite Beds at Doornoge Bay. Like ours, the specimens recorded by Dr. Smyth also have calices which are mainly flattened, so I was interested to find in the Austin Collection in the Liverpool Museum several specimens which are fairly round and solid. Over thirty specimens are labelled from Hook Head. This corresponds with the names in the MS. catalogue which are given as *Pentremites pentangularis*, *P. acutus*, *P. oblongus*, and *P. enniskilleni*. The last named is also given in the catalogue from Co. Fermanagh.

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EXPLANATION OF PLATE XV.

Figs. 11–15.—Photographs of Blastoids with the brachioles in position. In Fig. 11 a good part of the column is still attached. In Figs. 12, 13, and 14 the proximal portion of the column is also adherent. All from Hook Head, Co. Wexford. × 1½.

The Graptolitic Faunas of the Gotlandian in the Eastern Alps and their Relationships.

By Professor Franz Heritsch (Graz).

THE years that followed the Great War saw a rapid development in knowledge of the graptolitic faunas of the Eastern Alps. Professor M. Gortani described many graptolites from the Carnic Alps, and papers from the Geological Department of the University of Graz dealt with the same subject, as well as the distribution of the graptolites over a wider area of the Eastern Alps. Especially

noteworthy was the surprising discovery of graptolites in the so-called grauwacke zone of the Alps, which follows the southern margin of the Northern Calcareous Alps. In the grauwacke zone, which consists of Palaeozoic and more ancient strata, more or less metamorphosed, graptolites were found at the following localities, (*a*) Fieberbrunn in the Tyrol (1),[1] where the zones of *Monograptus cyphus* to *M. turriculatus* are found, and the presence of *M. priodon* indicates that higher zones may occur; (*b*) environs of Eisenerz in Styria (2), where the zones of *M. gregarius* to *M. griestoniensis* are found, as well as the zone of *M. nilssoni*; (*c*) Montavon in Vorarlberg (29), where a badly-preserved specimen of *Monograptus*, possibly *M. priodon*, was discovered.

Rastrites sp. has been found in the Palaeozoic region of Graz, in the lydites and black siliceous rocks which are of rare occurrence. Also, from the black siliceous shales of Murau, in the valley of the Mur, *Rastrites* sp., *Monograptus* sp., and *Diplograptus* sp. have been recorded (4).

These recent discoveries in the grauwacke zone and in the neighbourhood of Graz and Murau suggest that Gotlandian graptolites may be widespread in the Palaeozoic regions of the Eastern Alps. It is worthy of note, too, that Ordovician graptolites have been found at four localities in the grauwacke zone.

The first discovery of graptolites in the Carnic Alps was made sixty years ago by G. Stache (5), but it was not until the post-war years that detailed studies of the graptolitic faunas were undertaken, notably by M. Gortani (6). That investigator showed that important faunas of Birkhill-Gala [2] age are present, many of the species being found in Great Britain. He recorded some new varieties. The faunas of Wenlock age in the Carnic Alps include many species occurring in England (*M. vomerinus* Nich. and its variety *gracilis* Elles and Wood, *Cyrtograptus murchisoni* Carr., and *C. carruthersi* Lapw.), and one Sardinian species (*M. hemipristis* Meneghini). In addition, Gortani has demonstrated that the zone of *M. nilssoni* is present. But Gortani's results do not tell the whole story, for many of the graptolites were not collected in situ, with the result that the faunas of different horizons have not been differentiated. It is not surprising, therefore, that he concluded that the zonal system of Elles and Wood was not applicable to the Carnic Alps (for example, Gortani cited, as from the Wenlock fauna of the Dellacher Alp, *M. remotus* Elles and Wood, which occurs in the zone of *M. turriculatus*).

More recent work by E. Haberfelner (7), has shown that the distribution of the graptolitic faunas is in accord with the zonal succession of Elles and Wood. Investigations by Haberfelner, and also by another of my students, Ida Peltzmann, accounts of which

[1] Numbers in parentheses refer to the Bibliography at the end of this paper.
[2] The term Birkhill-Gala is used as indicating the graptolitic facies of the Lower and Upper Valentian.

will shortly be published, show that graptolites characteristic of the zones from *Mesograptus modestus* (or perhaps *Akidograptus acuminatus*) to *M. leintwardinensis* are present. Moreover, Haberfelner has found *M. kayseri* and *M. hercynicus*, which belong to the stage of $e\gamma$ of Bohemia (= lowest Devonian).

Although most of the graptolites known from the Carnic Alps have been found in Britain, there occur also species recorded from Bohemia and Scandinavia. It is interesting to note the presence of the genus *Stomatograptus*, not known in Britain. Moreover, the finding of Sardinian species in the Carnic Alps is of great significance. As examples may be cited *M. sardous* Gortani, *M. proboscidatus* Gortani, and *M. tariccoi* Gortani, from the Wenlock. I. Peltzmann has found that species of Sardinian character appear, indeed, as early as the time of the *M. griestoniensis* zone of the Gala. These species are similar to, but not identical with, the forms described by Bouček (8) from Bohemia. The true Sardinian species first appear in the zone of *Cyrtograptus murchisoni* (*M. proboscidatus* and *M. tariccoi*).

In all the graptolitic regions of the Alps, with one exception, the lowest zone of the Gotlandian (that of *Akidogr. acuminatus*) is missing. The exception is the Bischofalm Nappe in the Carnic Alps, in which the succession of Ordovician and Gotlandian rocks is complete.

In Bohemia, Bouček (9) has established zonal subdivisions between the beds which correspond to the zones of *M. crispus* and *M. riccartonensis* of the English succession. In these graptolite-bearing deposits, two species of Sardinian character appear, namely, *M. vomerinus* Nich. var. *robustus* Bouček (cf. *M. sardous* var. *eximius* Gortani) and *M. prosbosciformis* Bouček (cf. *M. mutuliferus* Gortani). Bouček (10) has also described a succession of shales and diabases of Valentian age in which occur graptolitic faunas of British type. The shales include the zone of *M. convolutus*, with graptolites known to occur only in England, and the zones of *M. turriculatus*, *M. crispus* and *M. griestoniensis*, in which most of the species are identical with those in the corresponding English faunas. The zone of *M. turriculatus* is here of considerable thickness; it is also thick and of wide extent in the Carnic Alps. Thus in Bohemia are found English and Scandinavian species in addition to purely Bohemian species, and in the Gala series, Sardinian forms.

The graptolitic faunas of the Balkan Mountains have been made known through the work of Allahverdjiew, Boncev and Haberfelner (11). The Birkhill-Gala, Wenlock, and Ludlow are said to be present, the Wenlock containing graptolites of the English, Bohemian and Scandinavian faunas, together with six Sardinian species.

We owe our knowledge of the beautiful preserved graptolites of Sardinia to the excellent work of Gortani (12). Both the Birkhill

and Wenlock (the latter including *Cyrt. rigidus* Tullberg and many Sardinian species) have been recognized, but faunas of Gala age have unfortunately not yet been found. It is therefore not possible to say whether or not the Sardinian area was a part of the Alpine and Bohemian Sea in Gala times. While species restricted to Sardinia are very abundant in the Wenlock, other species of *Monograptus* are few.

A review of the faunas in Spain and Portugal indicates that many difficulties remain to be solved. A rich fauna has been described from Birkhill Shales of Almaden (13), also graptolites of Birkhill-Gala age from the Hesperid Mountains (14), a Birkhill fauna from the Cantabrian Mountains (15), and faunas from the Pyrenees (27). But no Sardinian forms have been recorded from these localities.

A list of graptolites from near Barcelona, ranging from Birkhill to Ludlow forms, has been published by Schriel (16). All of these have been recorded from Britain, but in the collections of the Geological Department of the University of Graz are pieces of greyish-black siliceous shales from Vileta (Barcelona) with *M. dubius* Suess, *M. colonus* Barr., *M. roemeri* Barr., and one with *M. tariccoi*. Thus it would appear that at least one Sardinian species does occur in Spain.

The work of Delgado (28) on the occurrence of Sardinian forms in Portugal is important. His work shows that in the region of Villarinho de Cima the succession includes the zones from *M. gregarius* to *M. crispus*, species of *Monograptus* being frequent, with two species of *Diplograptus* and two of *Rastrites*. In addition he records *M.* cf. *lamarmorae* Meneghini and *M.* cf. *gonii* Meneghini, and mentions eleven species of *Monograptus* " que nous considérons toutes nouvelles . . . Plusiers de ces espèces sont remarquables par leurs énormes dimensions, les empreintes parvenant à atteindre 1 centimètre de largeur ; elles le sont aussi par le nombre des cellules qui s'élèves quelquefois à plus de 20, et d'autres fois descend jusqu'à 3 ou 4 en 1 centimètre de longeur de l'hydrosome ". There is little doubt that these are Sardinian forms.

The presence of Sardinian species in Spain and Portugal makes it probable, in my opinion, that the Sardinian graptolite sea extended into the region of the Iberian peninsula. It is remarkable, however, that at Villarinho de Cima, the presence of the greater part of the Gala has not been established on graptolite evidence.

Surveying the graptolitic faunas of Europe, we are able to set out the following conclusions :—

1. The graptolitic faunas of Lower Valentian age are of the same type throughout the whole of Europe, and the species are those characteristic of the Birkhill Shales in Great Britain.

2. The differentiation begins in the Gala.

(*a*) In Scandinavia, particular species of the *vomerinus* group appear, e.g. *M. personatus* Tullberg and *M. linnarssoni* Tullberg ;

with these species is associated *M. spinulosus* Tullberg, a spinose form which differs considerably from those of the *vomerinus* group. It is noteworthy that none of these three species is found in Great Britain, but one variety of *M. linnarssoni* (var. *flumendosa* Gortani) belongs to the Sardinian assemblage.

(*b*) In Bohemia the first Sardinian graptolites appear in the Gala.

(*c*) Similarly, Sardinian forms first appear in the zone of *M. griestoniensis* in the Carnic Alps.

3. The graptolitic faunas of the Wenlock of the Alps, Sardinia, and Bohemia differ considerably from those of Britain as a result of the presence of the Sardinian species. Light is thrown on the notable appearance of *Cyrtograptus* in the Wenlock by the work of Haberfelner (17), who believes that the genus takes its origin from *Monograptus*.

4. The graptolitic faunas of the Ludlow are similar over the whole of Europe.

The above conclusions help us to a realization of the palaeogeography of the graptolitic seas of Europe. The Nestor of graptolite investigators, Professor J. E. Marr, published a sketch-map of the area of deposition of the Stockdale Shales in Europe (18), which shows a deep gulf extending from the Atlantic Ocean across Great Britain into Scandinavia and Central Europe. Marr says, " In the quiet waters of such gulfs the fine sediments of the Stockdale Shales and their equivalents might well be formed, and the floating vegetation collected." Some features shown by the sketch-map are, (*a*) the gulf reaching from Scotland to the northern coast of Scandinavia, (*b*) the very great extension of the sea in south-eastern England, Germany, Bohemia, Sweden, and the Baltic provinces, (*c*) a peninsula between this great sea and the Mediterranean, comprising the area of the Alps and the southern part of France—a part of a great eastern continent.

But we now know that there was a sea between Bohemia and Sardinia. The graptolitic series of the Alps suggests that this sea connected the German and Mediterranean areas. All the regions with graptolitic shales were in communication in Lower Valentian time, but in the Upper Valentian this connection was not so complete between Germany and Bohemia, and between the Alps and Germany. In the Wenlock, open-sea conditions only existed between Bohemia, the Alps and Sardinia, while there was a bank interrupted by shallows, or a narrow chain of islands which in part prevented the intermingling of faunas, between this region and that of Great Britain and Germany. In the Ludlow, this bank or chain disappeared; free communication was possible once more between all the graptolitic regions of Europe.

We are forced to the conclusion that the Western Alps formed an island, for there were marine conditions in southern France as shown by the presence of the graptolitic series of the Montagne Noire, with Wenlock and Ludlow forms.

The graptolitic shales of Morocco belong to the Gotlandian Mediterranean Sea. The first graptolites were obtained by Gentil (19) from the lower part of the Gotlandian. P. Russo (20) has recently compiled a list of all the species found there.

The Gotlandian Mediterranean extended as far as Arabia, where Blanckenhorn (21) recorded some badly preserved graptolites. Also Frech, in his account of the geology of Asia Minor (22), states (p. 209) that "Obersilurische Graptolithenschiefer von der Hedschas Bahn (28° 20′ n. Br., 36° 48′ ö. L. Greenwich) erinnern an ähnliche Vorkommen Sardiniens".

The Gotlandian is not known to occur in Yugoslavia, Albania, and Greece, but rocks of Ordovician age have recently been proved by Desio (23) to occur in the island of Chios. As Devonian rocks are widely distributed in Asia Minor and in the region of the Bosphorus, and as there are limestones with *Halysites* recorded from the last-mentioned region, we may hope that the discovery of Gotlandian, possibly graptolite-bearing, will be made in due course.

The eastern continuation of the Mediterranean region of the graptolite sea included the area of the Balkan Mountains, but in the Caucasus the Gotlandian contains a non-graptolitic fauna which closely resembles the Bohemian fauna described by J. Barrande. But communication between the Caucasus and Bohemian Gotlandian seas could not have been directly east and west, because the Podolian Gotlandian of the northern (Baltic) facies is interposed. The connection can only have been by way of the Alpine area and the Mediterranean Gotlandian.

Graptolitic faunas indicating the occurrence of the zones from that of *M. cyphus* to *M. griestoniensis* (excepting *M. convolutus*), and *M. nilssoni*, *M. scanicus* and *M. leintwardinensis* have been found in the southern part of the Urals. Sardinian forms have not yet been recorded from this region. Passing to Eastern Turkestan, B. Averianow (26) has produced evidence of graptolitic faunas of Birkhill Gala, Wenlock, and Ludlow age. Most of the graptolites are known from Great Britain. Averianow has described a new species, *M. ferganensis*, from the Gala, which is very broad (3·5 to 4 mm.) and has a small number of thecae (5 to 6 in 10 mm.). It appears to be of Sardinian character. Probably, a variety of *M. vomerinus*, named by Averianow, var. *major*, also belongs to that group. These records suggest that the graptolitic region of Turkestan was an extension of the Mediterranean.

If we may venture to generalize, it seems that the evolution of Sardinian forms took place in those regions which show the Bohemian facies (Barrandian) of the Gotlandian. The problem of whether the Sardinian forms have evolved from the English species or whether they migrated from other regions cannot at present be solved, but it seems probable that the former is the true explanation.

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The Granitic and Basaltic Areas of the Earth's Surface.

By G. F. S. Hills.

THERE are many reasons for believing that the floor of the oceans, at least of the Pacific, consists of basaltic rocks as distinct from the granitic rocks which form the continents. It is here suggested that this non-uniform distribution of rocks over the earth's surface may have been caused by the particular kind of cooling mechanism which was adopted in the early stages of the earth's history. A stage would be reached when granite would separate out as a lighter mass resting on the heavier and still liquid viscous basalt.

Two cooling mechanisms to provide for the escape of heat seem to need consideration :—

(*a*) The formation of a granite crust completely covering the liquid material, but of such thickness as to permit the steady escape of the heat arising within it and convectively brought to its under surface.

(*b*) A separation of the surface into two parts, one a surface of granite crust, thicker than under (*a*), the other a free surface of liquid basalt which latter would afford a direct convective means of escape of heat.

It is difficult under (*a*) to account for the existing non-uniform distribution of rocks and this suggests that consideration might be given to (*b*). The analogy of the convective processes in a pot of jam slowly boiling over a fire is interesting in this connection. In the case of the boiling jam a light scum forms on the surface, but this is drawn aside by surface tension from the centre where the upward convective current maintains a free surface clear of the scum, the scum being piled up in a surrounding ring.

If (*b*) was in fact the mechanism adopted, the basaltic surface would later solidify and this non-uniform distribution of rocks would be permanently preserved. As a preliminary step towards justifying alternative (*b*) it would be necessary to show that forces exist adequate to clear the convective surface analogous to the force of surface tension in the case of the jam.

A further question that arises is whether, after the solidification of the basalt surface and in particular after the blanket of the ocean had covered the basalt, the cooling mechanism afforded by this non-uniform cover would permit of a steady state in view of the heat produced by radioactivity or whether a rifting of the granite continents would be necessary, so as to provide an additional means of escape.

The " seas " on the moon may in this view be part of the convection cooling mechanism, but the history of the moon after the complete solidification of its surface would probably be different from that of the earth as it has no ocean cover.

Note on Mr. Hills's Paper.

By Harold Jeffreys.

MR. HILLS'S paper suggests a number of questions, some of which can be fairly definitely answered, while others seem to me to be worth recording on the principle that the best way to get a question answered is to ask it. The separation of the granitic material into limited regions of the earth's surface to form the continents could clearly not occur when the earth was fluid, and after the earth solidified any mechanical cause would meet formidable difficulties. Explanations seem to be restricted to (1) a failure or partial failure of magmatic differentiation in the oceanic regions, so that the granite has separated out since solidification in the continental regions, but remained dissolved in the oceanic ones, (2) some mechanical process arising during solidification. There are difficulties about both possibilities. Mr. Hills's theory belongs to the second class, and I think needs serious consideration.

A more fundamental question still is that of the mechanism of the

vertical separation, apart from the horizontal one. When I first became interested in these problems it was widely believed that isostasy was general, and that it was due to a granitic layer of variable thickness resting on a basaltic one extending down to the central core, the mass per unit area being kept uniform by a depression of the interface where the outer surface is elevated; and that the granitic and basaltic material separated originally through being immiscible in the liquid state, like oil and water. Later work has shown that this view is in some respects too simple and in others definitely wrong. Seismological evidence is consistent with the upper layer being granite, but the velocities in the deep material are too high to be attributed to basalt or any material of similar composition. They would fit olivine, but no less basic material. There are also at least one, and possibly four, intermediate layers, one of which might be dolerite or gabbro, but the existence of this one is less convincingly supported than that of any of the others.[1] I originally suggested that the best established one might be vitreous basalt or tachylyte, but several alternatives are available (of which crystalline basalt or gabbro is not one), and when I am not specifically concerned with its composition I prefer to call it simply "the intermediate layer". Fortunately all the materials that would give the correct velocity of transmission have about the same density, so that the identification does not affect questions of isostasy. No near earthquake work has yet been done in oceanic regions, on account of scarcity of stations, so that the upper layers below the ocean are not yet investigated. The existence of an intermediate layer introduces some latitude into the interpretation of isostasy, which seems to provide explanations of some geological phenomena.[2]

The apparent uniformity of the upper layers is indicated by the possibility of tracing the pulses transmitted in them to distances of 800 km. or so, with only small and possibly insignificant changes of velocity. The thicknesses are of the order of 10 km. Separate pulses would exist whether the transitions between them were sharp or gradual, and the only real test seems to be the presence or absence of definite reflexions. Now a seismogram normally shows a series of pulses, each followed by a train of waves. A number of possible causes of dispersion have been suggested to account for these trains, but all have been investigated and found to give qualitatively different results: mere blunting of the beginning of a phase, or a gradual increase in the amount of the displacement without change in its direction.[3] The only surviving cause seems to be internal reflexion in the upper layers. The sedimentary layer would be capable in some cases of accounting for the shorter periods; but some

[1] *M.N.R.A.S. Geoph. Suppl.* iii, 1933, 131–156.
[2] *M.N.R.A.S. Geoph. Suppl.* ii, 1931, 323–9; *The Earth*, 1929, 294.
[3] *M.N.R.A.S. Geoph. Suppl.* ii, 1931, 407–416; *Proc. Roy. Soc. A.*, 138; 1932, 294.

movements seem inexplicable except as reflexions either at the base of the granitic layer or the top of the lower layer.

On the hypothesis of liquid immiscibility such sharp transitions had a simple explanation, but experimental evidence has now led petrologists to abandon this hypothesis,[1] and we must look for an alternative explanation either of the discontinuities or of the pulses that look like reflexions. Crystallization in suitable circumstances can certainly give discontinuities. I keep sodium sulphite for photographic purposes in a saturated solution, which forms a crystalline mass at the bottom with a flat, smooth surface. If the whole was frozen there would be a discontinuity between solids of the required type. If instead of sodium sulphite we had the carbonate, which dissolves in its own water of crystallization when slightly heated, the proportions of the materials in the earth could be imitated. The salt need only be dissolved in an amount of hot water slightly exceeding the required water of crystallization, and the result on cooling will be a mass of crystals with a small amount of solution over it, quite analogous to the rocky shell of olivine, nearly 3,000 km. thick, with about 30 km. of other rocks on top.

Unfortunately the conditions in the early history of the earth were more complicated. Even when olivine had ceased to separate as a rock of one constituent, the magma above it contained many substances in solution. If only one constituent separated at a time and settled to the bottom we should have a series of layers each consisting of one mineral or an isomorphous mixture, but such uniform rocks do not correspond to known igneous rocks. It is difficult to suppose that when a complete separation had once taken place the later igneous phenomena should so regularly have mixed the constituents again. At present at least we must suppose that the layers crystallized as mixtures and are so still. The proportions would in general vary as different materials became exhausted, and the variation might naturally be expected to be continuous. I do not think that this need imply that the variation of the proportions of the constituents should be linear or even approximately so, and if it did the result would be inconsistent with the existence of the nearly uniform layers revealed by seismology. There must have been stages when various constituents became exhausted and the later crystallization was in terms of a balance between others; and as exhaustion is a gradual process we should expect continuous transitions in composition. Our question is, how thick would the layers of transition be? The problem is perhaps partly analogous to the downward concentration of the heavy molecules in the upper atmosphere, but I can only leave the solution to somebody more expert in physical chemistry and petrology than I am. If a marked change of composition due to differentiation can take place within a depth of 2 km. vertically, we may be able to explain the reflexions;

[1] Bowen, *Journ. Geol. Suppl.*, xxiii, 1915, 9.

if it cannot take place within 10 km., we cannot explain the layers. Field observation also may provide relevant information.

The formation of the thick lower layer by separation of olivine was, I believe, first suggested by Rastall[1]; I adopted it in the second edition of *The Earth* (p. 155) as a natural extension of some work of Bowen. The material would in any case be a mixture and would not have a sharp melting-point, so that it would pass from the liquid state to the solid through that of a paste or sludge, with a high viscosity rising continuously as the temperature fell and the liquid was squeezed out. Solidification would be from the bottom up, and it is probable that the upper layer was still liquid when the lower one was already stiff. But stiffness is a question of degree, and it is not perhaps out of the question that the rapid loss of heat from the surface solidified the upper layer before the lower one had cooled much further.

At the stage Mr. Hills is considering, the original heat brought to the surface would be 500 or 1,000 times that received from the sun, and would therefore overwhelm that generated by radioactivity. In these conditions we should expect rising currents in some places and descending ones in others. The free surface would be elevated above the rising currents and depressed over the descending ones, the rising material turning horizontally at the surface and travelling to the places where it sinks again. Such horizontal currents would tend to carry floating matter to the depressed regions. Surface tension would be negligible; the effect of gravity would be to carry matter towards the places where gravity is least, as in the Polflucht of Eötvös. It is not, I think, quite obvious whether gravity would be high or low over the elevations; the extra height implies extra depth, but the temperature would be higher and the density lower. Thus it is not clear whether the effect of gravity would assist or resist the effect of the currents; but it can hardly be expected to balance them exactly, and if any residual effect remained floating matter would tend to collect either at the elevations or the depressions, more probably the latter. When once collected it would tend to hold itself together, since the force between two floating bodies is an attraction.[2]

An analogous mechanism seems possible even before the surface layers became solid, since a fluid outer layer would naturally be drawn to the depressed regions by gravity alone. This would avoid the difficulty about seeing how the surface layers could behave as a solid while the lower one was still liquid. Both ideas involve a quantitative question: whether the differences in level produced by convection currents could be enough to produce complete separation with the actual amount of granite. The answer will probably depend on the viscosity of the material, and cannot be given until

[1] *Nature*, 115, 1925, 647; Geol. Mag., LXVI, 1929, 453.
[2] *The Earth*, 1929, 302; *M.N.R.A.S. Geoph. Suppl.* i, 1926, 418.

we know much more than we do at present about the viscosity of liquids or semi-liquids at high temperatures and pressures.

The idea that the distinction of continental and oceanic structure is due to a difference in differentiation since solidification would agree with the frequency of igneous activity at the present day, which at least shows that differentiation is not yet so complete as it may some day become. It is less obviously consistent with the present distribution of gravity. If differentiation of acidic material is less complete under the oceans we should expect the same to be true of radioactive material, which would therefore be the same in total amount (per unit surface area) but distributed through a greater depth. In these conditions cooling would be less under the oceans and the material weaker. This does not correspond to the large gravity anomalies found by Meinesz and to the frequency of deep-focus earthquakes below the oceans, which imply a strength at great depths comparable with that at the surface.

Accordingly, while the matter cannot be considered settled, Mr. Hills's appeal to the vertical convection currents generated during the highly viscous stage seems to be the most plausible explanation of the restriction of the granite to limited regions that has yet been offered.

Note on the Fishes of the Ruabon Marl.

By H. H. Simpson, B.Sc.

IN Denbighshire the Marl follows the productive Middle Coal Measures and consists of from 400–1,100 feet of red, green, and variegated marls with occasional sandstones and towards the top thin Spirorbis limestone and other limestones, with here and there films of coal. It corresponds with the Etruria Marl of the North Staffordshire Coalfield.

No organic remains have been found in the lower part up to the region of the Spirorbis limestone, but in this occasional fish remains have been recorded.[1]

The section of the upper 30 feet, where exposed in an open pit near Ruabon, is as follows :—

	ft.	in.
Marly limestone D	1	3
Marl, purple	1	9
Marly limestone C	1	0
Marl	15	0
Limestone, compact, B		5
Brick-red marl	9	0
Variegated shale, laminated	1	0
Blue-grey shale		3
Spirorbis limestone		1–3
Grey shale		6
Coal film		½
Grey shale		6
Coal film		½

[1] "The Geology of the Country around Wrexham," part ii, p. 103, *Mem. Geol. Surv.*, 1928.

From the under side of the Spirorbis limestone the following have been collected from one part of the quarry :—

Gyracanthus sp. Spines and fins.

Megalichthys sp. Teeth, scales, and bones.

Ctenodus murchisoni Ag. MS., Ward. Palate.

Ctenodus? Ribs.

Callopristodus pectinatus Ag. Teeth.

The limestone thins out to the south, and as no other identifiable fish remains are to be found at this horizon elsewhere in the pit, it appears as if these fishes had been overtaken by some disaster at the bottom of a shallowing pool.

In the blue-grey shale and laminated shale above the Spirorbis limestone, scales, spines, and teeth of small fishes are quite common, but so far there is no trace of *Megalichthys* and *Gyracanthus*.

Limestone B contains numerous teeth of *Callopristodus pectinatus* together with small scales, spines, and bones.

Limestones C and D. This is a marly rock and contains no trace whatever of organic remains, and more than any of the other limestones has the appearance of a chemical precipitate.

The presence of two species of shark-like fishes at one horizon only, calls for some explanation. It will be noticed that the shales immediately above this horizon lose their red colour and become grey-blue, a colour often associated in the Middle Coal Measures with marine bands. It appears as if the inland lakes [1] had been broken into by the sea about this period, if only for a short time, as evidenced by the further deposition of red marl.

I am indebted to the Geological Survey and to Professor D. M. S. Watson, F.R.S., for the determination of the fish remains.

[1] *The Building of the British Isles*, Jukes-Browne, p. 176.

REVIEWS.

DIP AND STRIKE PROBLEMS MATHEMATICALLY SURVEYED. By KENNETH W. EARLE. pp. x + 126, with 122 figures in the text. London: Murby and Co. 1934. Price 12*s.* 6*d.* net.

THIS book is designed to aid in the solution of those geometrical questions which often arise in mining and other applications of field-geology. As appears from the bibliography at the end of the volume, numerous writers have already dealt with the subject, though not on so elaborate a scale. It may, indeed, be thought that the author has sometimes erred on the side of over-elaboration. The very full discussion of the effects of faulting e.g., illustrated by a multiplicity of diagrams, really gives no more than any intelligent student could supply for himself.

For most of the problems treated the reader is offered his choice of trigonometrical calculation or graphical construction. It is objected to the latter method that its results are only approximate; but in nature dips and slopes seldom make true inclined planes, and there is little gain in making calculations more accurate than the data warrant. The reviewer may perhaps be excused a personal interest in pointing out an omission from the bibliography. The notes on the use of the protractor (pp. 115–17) are taken from an early contribution, while a later revision, with simplified treatment, has been overlooked (*Sci. Proc. Roy. Dubl. Soc.*, 1893). Doubtless there will be some who, like the author, prefer the trigonometrical method, and for them this book should provide a useful guide.

A. H.

GEOLOGY OF THE KING'S BAY REGION, SPITSBERGEN. By A. K. ORVIN. *Skrifter om Svalbard og Ishavet.* Nr. 57. pp. 195, with 3 plates, 4 maps, and 52 text-figures. Oslo: Jacob Dybwad, 1934.

THIS memoir is ostensibly devoted to a description of the coal-bearing property owned by the King's Bay Kul Comp. A/S, on the west coast of Spitsbergen, but the author manages to introduce a good many references to the general geology of the region, which has long been known by repute to British geologists as the scene of the work carried out by Garwood and Gregory on the glaciers in the last decade of the nineteenth century. Furthermore, a good description is given of the Hecla Hoek formation, which the author considers to range from Ordovician downwards, probably into the Pre-Cambrian. The other systems present are Devonian, Middle and Upper Carboniferous, Permo-Carboniferous, and Tertiary. The Carboniferous facies is interesting, as the middle part belongs to the Russian (Moscovian) type and the upper part is described as a *Cyathophyllum* limestone; Mesozoic rocks are completely absent,

hence the age of the structures affecting the Palaeozoic is difficult to determine—at any rate there is pre-Tertiary folding and overthrusting on a considerable scale, some of it certainly Caledonian though pre-Downtonian, while the Tertiary coalfield is much faulted.

The coals are of Lower Tertiary (Eocene) age and the plant fossils indicate a warmish temperate climate of the present mid-European type. The coal proved of great value to Norway during various English post-war coal-strikes, but working ceased in 1929. The total output seems to have been rather less than a million tons.

THE SEQUENCE OF FLORAS IN THE UPPER CARBONIFEROUS, WITH SPECIAL REFERENCE TO SOUTH WALES. By EMILY DIX, D.Sc., *Trans. Roy. Soc. Edin.*, lvii, 1933, 789–838.

IN this paper Dr. Dix gives a detailed account of the flora of the Swansea area. The results are substantially the same as those published by the present writer in *The Geology of the South Wales Coalfield*, Pt. V, *Merthyr Tydfil*, 1933. In addition, however, Dr. Dix has identified Stephanian measures in areas adjoining Merthyr Tydfil.

The South Wales Coal Measures are divided by Dr. Dix into nine plant zones by means of floras " A " to " I ". The diagnostic species are: Flora A :—*Lyginopteris stangeri*, *Alethopteris* cf. *parva*; Flora B :—*Pecopteris aspera*; Flora C :—*Neuropteris schlehani*, *Lyginopteris hoeninghausi*; Flora D :—*Alethopteris lonchitica*, *Neuropteris heterophylla*; Flora E :—*Lonchopteris rugosa*, *Neuropteris gigantea*, *Sphenophyllum myriophyllum*, *S. majus*, *Annularia microphylla*, *Sphenopteris* spp.; Flora F :—*Neuropteris tenuifolia*, *N. callosa*, *Asolanus camptotaenia*, *Lepidodendron simile*; Flora G :—*Neuropteris rarinervis*, *N. linguaefolia*, *Linopteris münsteri*, *Mariopteris sauveuri*, *M. latifolia*, *Sphenopteris striata*, *Renaultia chaerophylloides*, *Asolanus camptotaenia*; Flora H :—*Neuropteris ovata*, *N. scheuchzeri*, *N. flexuosa*, *Odontopteris lindleyana*, *Alethopteris serli*, *Asterotheca abbreviata*, *A. cyathea*, *A. arborescens*, *Sphenopteris neuropteroides*, *S. macilenta*, *Diplotmema geniculatum*, *Sphenophyllum emarginatum*, *Annularia stellata*; Flora I :—*Asterotheca lamurensis*, *Acitheca polymorpha*, *Odontopteris* sp., *Alethopteris grandini*, *Sphenophyllum oblongifolium*.

Some of these floral zones are admittedly not well defined, but the paper marks further progress in the subdivision of the Upper Carboniferous rocks and will, no doubt, eventually pave the way towards a more unified classification based on floras and faunas.

Much of the subject-matter regarding the lowest zones has been published elsewhere (*Palaeontographica*, Bd. lxxviii, B, 168–202) and was reviewed by the present writer in GEOLOGICAL MAGAZINE, LXXI, 1934, 134–6.

With regard to Flora A, Dr. Dix states that it probably corresponds roughly with the goniatite zones E and H (p. 796). Flora B

does not appear to be particularly characteristic so far as this country is concerned. The *N. schlehani* zone is regarded as comprising all the beds from near the base of the goniatite zone G up to a short distance below the Lower vein (p. 797). The zone of *A. lonchitica*, etc., corresponds with the upper part of the zone of *Carbonicola ovalis* and the zone of *Anthracomya modiolaris* (p. 800).

The *Lonchopteris rugosa* zone ranges from below the Nine-feet vein to above the Soap vein and coincides with the lower part of the zone of *Carbonicola similis* and *Anthracomya pulchra* (p. 804). Flora F, represented by *N. tenuifolia*, etc., is not distinctive, being " transitional in character between that of the preceding zone and that of the succeeding zone " (p. 805); the lower limit is taken at about 1,749 feet in the No. 1 Borehole at Cwmgorse and the upper at the Lower Pinchin seam, where *Anthraconauta* begins to appear. Flora G ascends to a short distance below the Glyn Gwilym seam.

Flora H " is characterized by the complete absence of *Neuropteris tenuifolia*. The dominant plants include *N. flexuosa*, *N. scheuchzeri*, etc. (p. 813). The zone ranges from the Glyn Gwilym to the Wernffraith seams and " coincides with the zone of *Anthraconauta tenuis* and the uppermost portion of the zone of *Anthraconauta phillipsi* of Davies and Trueman. Up to the present, however, non-marine shells have not been discovered in the beds between the Glyn Gwilym and the Hughes veins, and future work may possibly remove this small discrepancy between the plant and animal zones ". (p. 813).

" The zone characterized by Flora I corresponds roughly with the Upper Coal Series except that it has been thought advisable to include the Wernffraith seam in the underlying zone pending further investigation " (p. 814).

Dr. Dix then passes on to the eastern portion of South Wales (near Gilfach Goch). Here Floras A and B have not been recognized, while Flora C appears to be represented by a single record. Flora D is fairly similar to that found near Swansea, but a number of typical species are missing from Flora E. In general, the succeeding Flora, F, resembles that at Swansea. The lower limit of the zone corresponding to Flora G is at the No. 3 Rhondda seam and the upper limit is suggested a short distance below the Cefn Glas seam. Most of the Swansea zonal plants in Flora H occur in the east, though two are missing. The range of species in the uppermost zone, represented by Flora I, requires working out in detail.

Further comparisons are made with Pembrokeshire, Devon, North Staffordshire, Yorkshire, Northumberland, and Scotland as well as general comparisons with Continental areas.

The correlation of the uppermost Coal Measures of Swansea with the Lower Stephanian of France constitutes an important conclusion, this being the first record of a definite Stephanian flora in Great Britain.

R. Crookall.

CORRESPONDENCE.

MECHANISM OF EARTH MOVEMENTS.

SIR,—May I be allowed to thank Mr. MacGillavray for reading my paper carefully? In reply to his letter (GEOLOGICAL MAGAZINE, March, 1934) all his criticisms are levelled at the possibility of a crust oscillation, and I need hardly say that when this idea first presented itself I was quite as astonished as Mr. MacGillavray. I did not use the undeserved term "theory", but considered that the fittest thing was to describe shortly step by step the direction in which several years' work had led—leaving out, of course, all the blind alleys explored. For this reason the paper was entitled "A Search for, etc." and my hope was that someone would come forward and help me to look for the fire behind all this smoke. Any discussion or criticism is welcome which will help to clear up the matter.

"Whether . . . the equality of terrace intervals between different sites" really exists cannot, I think, be questioned, for it formed the basis of the eustatic hypothesis associated with Depéret's name.

(1) This is so; I could make nothing of these steps and presumed that independent fluctuations of lake-level had masked the effect of earth-movements, if any.

(2) I was referring to deficiencies above the axis, and admit I should have said so: the question of impulses from below was being held strongly in mind, so that only the relationship of the movements on one side seemed important. The figure of 1·79 was not selected at random: it is the square of 1·34, which is the ratio given by 247/330, and the dotted curve was extended backwards over the larger movements to see if any relationship would emerge. The only arbitrary feature about Fig. 5 is the axis, and my critic's *reductio ad absurdum* leaves me unmoved, because taken separately many of these points can be torn to pieces, but together they begin, as the Chinese say, to "cast a shadow".

(3) The Old Wolvercote Channel would have been cut more deeply only if all the erosion occurred at the same place. One phenomenon of river action is the abandonment of one channel and the cutting of another. Also I should not be so bold as Mr. MacGillavray and assume the same amount of water to run throughout various ages. Fig. 8 is only intended to be qualitative and not quantitative as Fig. 10; moreover, if the two are to be compared, the first trough in the latter, and not the buried channel, is to be correlated with the Summertown-Radley channel.

(4) I do not follow Mr. MacGillavray here. My argument is (p. 507) that both styles of curve result from the same original crust action proceeding from below, but that the Bilbao type shows a falling-off from the Nive type, which is the more common.

(5) It is misquoting to say I speak of a *rising* of the coast here. The rise preceded the movements in Table 2 and the last column shows the irregular subsidence. Fig. 15 is an attempt at the difficult task of illustrating the suspected movements : it is drawn to show sea-level rising and falling because the beaches are disposed in that manner, but the curve must be inverted for the land movements—

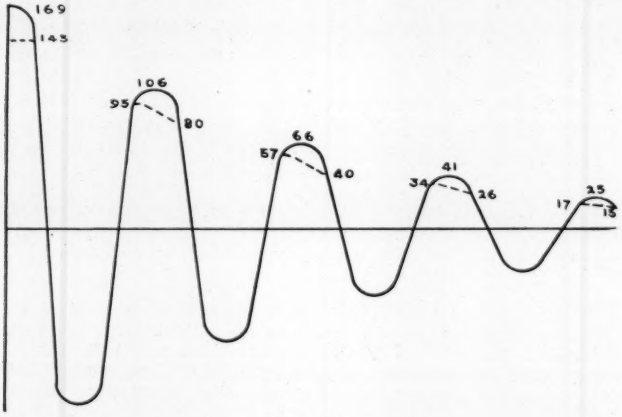

Fig. 15.

Spain in full and France, where it varies, in dotted lines. In another manner, the difference in behaviour can be appreciated if a soft rubber ball is placed on a table and one's hands held thumb to thumb palm downwards at some distance above it, the left to represent Spain, say, and the right France. Both hands are brought down together, the left on to the table and the right on to the ball which first gives way to a certain extent and then—if allowed—raises that hand a small amount; cf. p. 516, "as if a substratum had an elastic quality."

(6) Suggestions are welcome, but after examining Fig. 4 and Table 1 I do not think the first suggestion will be widely received.

R. G. Lewis.

PETROLOGY AND THE WESTERN RIFT OF CENTRAL AFRICA.

Sir,—In the article by A. W. Groves in the Geological Magazine for November, 1932, a very careful and satisfactory petrological account of certain features of the old rocks of Uganda in the vicinity of the Western Rift is given, about which there will probably be little difference of opinion. The interpretation of these characters in relation to Rift movements appears, however, to be far less satisfactory and by no means convincing.

One would readily agree with Dr. Groves in his observations on

pp. 498 and 499 that the " mortar-structure ", microscopic thrusts, and mylonization have been brought about by some severe earth movements, subsequent to the cessation of conditions of plutonic metamorphism, that is to say, after the rock had been brought by denudation nearer to the surface, but when he later refers the period of this and other changes, such as the conversion of hypersthene into garnet and the production of garnet-amphibolites from dolerite dykes, to mid-Pleistocene and Recent times his deductions seem open to question. They certainly do not conform with observations made in Tanganyika Territory by the members of the Geological Survey.

The specimens described presumably came in some cases from places at or near the present surface, which cannot be very different from that which prevailed in mid-Pleistocene to Recent times. According to Groves's contention, therefore, there cannot have been much lowering of level by denudation since these cataclastic structures and mineral changes took place in the rocks described. The relatively small amount of progress in rejuvenation in many stream courses on or near the scarps is clear evidence of the insignificant amount of peneplanation since the Rift troughs were formed. Is it reasonable to assume that such profound structural changes took place at such shallow depths ? It is perhaps significant that the features described are all confined to the old crystalline rocks of the Basement Complex. Have any corresponding structures been noted in younger rocks, either igneous or sedimentary, of Paleozoic, Mezozoic, or even early Tertiary age ?

So far as I am aware, such evidence is markedly absent concerning the rocks along the margins of Lakes Tanganyika, Rukwa, and Nyasa.

In the Lupa goldfields, an area lying between two powerful scarps and where most detailed examination has been made in Tanganyika Territory, mylonization and other shear phenomena similar to those described by Groves are well developed, but it is clear that these features are very ancient and long antedate the present scarps which cut across the old lines in nearly every case. One would like to see more evidence quoted from observations relating to the later rocks of Uganda. It cannot be doubted that the features described are due to extensive compressional forces, but, unless the period when these were imposed can be more satisfactorily established, I would hesitate to accept them as having anything to do with tectonic movements of so late a period as mid-Pleistocene to Recent.

My own experience in Tanganyika Territory is that they are much older than the Rift fractures which everywhere are best interpreted as associated with block movements.

I would like to add some remarks by Mr. G. M. Stockley, who has done a considerable amount of field work in the neighbourhood of the Nyasan Rift Valley in the South-West Highlands.